Presentations from the 2005 TechCon
- Vacuum Web Coating
- Large Area Coating
- Winning Poster

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On the Cover
Large area coating by double source spotless arc deposition of titanium and its compounds in a web coater. Photo courtesy of VON ARDENNE Anlagentechnik GmbH, Germany.

Errata: 2005 Summer Bulletin
1. The photo on page 10 shows Jennifer Kruschwitz, JK Consulting, presenting information in the Optical Coating session at the 2005 TechCon.
2. The sentence in italics was omitted from the discussion of Ekkehart Reinhold’s “Large Area Coating” presentation (page 10). The text should read: “He discussed electron beam deposition for large area applications and how, typically, deposition rates for some materials are higher for EB, but the layers are more porous and less dense than sputtered films and consequently have poorer durability and lower index. Reinhold discussed SAD (spotless arc deposition), which is a plasma activated process for improving the properties of EB deposited materials while retaining the high rates. TiO2 was specifically discussed.”
Summer is ending, and SVC is looking forward to our fall activities. Our Fall Board of Directors (BOD) meeting will be in November at the location of the AVS International Symposium in Boston, MA. Traditional activities for the fall Board of Directors meeting are the annual budget and planning for the next TechCon. Our 2006 budget planning is well underway by our Treasurer, Michael Andreasen, and the SVC management office. Fortunately, unlike several other technical societies in the post 9/11 era, SVC is financially very sound. The 49th SVC TechCon in 2006 will be held April 22–27, (save these dates!) at the Marriott Wardman Park Hotel in Washington, DC. We already have received many excellent abstracts and have arranged for several international and domestic invited speakers. The 2006 TechCon will be another great conference, and what a wonderful location!

Just like the seasons, changes are occurring here and worldwide that affect our industries, our employers, our jobs, and the SVC. I am particularly reminded of this as I write this article on the weekend of the fourth anniversary of 9/11 and in the aftermath of Hurricane Katrina. Therefore, a new activity in association with the November BOD meeting is a half-day strategic planning session. The objective is to focus the Board’s efforts on the really important issues for the future of the Society.

Recall that in conjunction with the Summer BOD meeting at the 2006 TechCon site, we included a “Best Practices” training session for the Board and held our first half-day strategic planning session. I want to thank Don McClure, an SVC Past President, for presenting the Best Practices session and for assisting as facilitator during our strategic planning efforts. Using the Best Practices methodology, members of the BOD and the Long-Range Planning Committee (LRPC) attempted to identify and prioritize the top strategic issues for the Society’s future. SVC Director, Paolo Raugei, has considerable experience in strategic planning and took a leading role in the session and in preparing a draft framework for a Strategic Plan.

As many of you know, strategic planning, especially with a fairly large group, is difficult and time consuming. However, I believe it is critical that the Board be personally involved in setting the future direction of the Society. Two action items for the LRPC are distilling the results of the summer strategic planning session and recommending to the BOD how to proceed at the Fall Board Meeting strategic planning session, including consideration of using a consultant or facilitator going forward. As we make progress in our strategic planning and have specific recommendations, I will report them to you.

As we face new challenges in the Society, I request your participation in influencing the course of the SVC. Please help us to be successful in these strategic planning tasks by providing your opinions and feedback on issues that are important to you. You may contact any member of the Board or LRPC (see SVC the Web Site for contact information); Pete Martin, (peter.martin@pnl.gov) SVC Vice-President and Chair of the LRPC; our Executive Director Vivienne Mattox (svcinfo@svc.org); or me (cibright@mmm.com). We always welcome your ideas, your help, and your support.

Clark Bright, 3M Company (cibright@mmm.com) is the SVC President.
The changes in vacuum coating have been a series of major and minor steps in equipment and processing and the application of the resulting coated materials. Often these steps have been foretold by previous techniques.

As early as 1920, sputtering was used to deposit metals on small mirrors (see paper #9 on the SVC Web Site/History/Historical Papers). The procedure used was to turn on the high-voltage sputtering supply before the pump-down began. That produced what we now call “reactive plasma cleaning” during pump-down. In the early 1930s, resistive thermal evaporation of aluminum from an array of tungsten filaments allowed the coating of large astronomical mirrors. By the late 1930s, thermal evaporation allowed the coating of optics with single-layer anti-reflection coatings. This effort was advanced during WWII by both the Germans and Americans (see papers #1 and #2 on the SVC Web Site/History/Historical Papers).

The mid-1950s brought sputter cleaning to the forefront as surface scientists strove to generate atomically clean surfaces. The 1950s also brought the development of ion sources for space propulsion. Today these ion sources are extensively used in vacuum coating. The early 1960s brought the technique of sputter cleaning and concurrent energetic ion bombardment of the depositing material to vacuum coating—first to improve film adhesion, then to tailor film properties such as density and stress. The mid-1960s brought the development of electron beam evaporation and the ability to thermally evaporate many more materials than could be evaporated or sublimed with resistively heated filaments and boats.

The very popular planar magnetron sputtering design was developed in the early 1970s. A disadvantage of the complete confinement of the electrons was the lack of electrons to produce a plasma between the source and substrate. Plasma activation and accelerated ions from a plasma are important in reactive deposition processes. This lack of plasma was overcome with the unbalanced planar magnetron sputtering (UBM) source and then with the linking of the magnetic fields of several UBM sources to form a hollow multisided source with the substrates inside. Higher deposition rates brought thicker deposits and the phrase “thin films” was no longer a good descriptor for many vacuum deposits; hence the use of the term “vacuum coatings.”

Reactive sputter deposition of hard and decorative coatings began in earnest in the early 1980s. Reactive sputter deposition requires accurate and reproducible mass flow control and partial pressure control. Reactive (oxygen and nitrogen) and inert gas (argon) mixture control began in the early 1980s using optical emission spectroscopy (OES) and mass spectrometry (MS). Spatial uniformity of plasma parameters and chemical composition required careful design of the gas inlet manifolds. Later, chemical vapor precursors containing carbon allowed complex Me-N-O-C compositions and layered structures to be deposited.

Careful control of gas and vapor compositions optimizes the sputtering deposition rate, properties, and color of the deposited material. Concurrent bombardment enhanced density and hardness of the deposited material. Reactive deposition of optical and transparent conductive oxide (TCO) coatings also advanced as the equipment and reactive process control technologies advanced. Reactive deposition of dielectric materials was improved by the use of “dual cathodes,” where the electrodes of the material to be deposited are alternately the anode and the cathode to the sputtering circuit. This minimized target “poisoning” and the “disappearing anode” effect where the anode of the plasma circuit becomes covered with an insulating material and shifts to another area. This changing anode position changes the plasma configuration. Pulsed biasing of the substrate also was developed to improve the properties of deposited dielectric materials.

Another problem with planar magnetron configurations is low target material utilization; therefore target costs are high. Target utilization can be improved using moving magnetic fields or by passing the target material through a stationary magnetic field as is done with the rotatable cylindrical magnetron cathode configuration.

Because under equilibrium conditions only a small percentage of sputtered material is ionized, post-vaporization ionization was of interest in the 1970s and 1980s. Ionization allows the atoms of the sputtered material to be ionized and then accelerated to add both kinetic and ionization energy to the depositing species. The movement of the ions also can be controlled in a version of “collimated deposition.” Post-vaporization ionization could be enhanced by increasing the plasma density through which the sputtered species travels to the substrate. In 1999, Kouznetsov et al. introduced “high-power pulsed magnetron” sputtering (HPPMS) in which very high powers were passed through the sputtering cathode while the average power remained within the limits imposed by target cooling. This HPPMS technology results in higher ionization of the sputtered species.

Anodic arc vaporization, from a molten anode, has been used for vacuum coating since the 1970s. Cathodic arc vaporization began to be used for vacuum coating in the 1980s. The cathodic arc may be forced to travel over a solid surface by the position of the arc anode, by applying a magnetic field, or by changing the arc electrode contact positions. Arc deposition has the advantage of generating high ionization of the vaporized material, but cathodic arc vaporization results in molten particles (“macros”) that may be unacceptable in the deposited coating. Various configurations are available for filtering the macros (and neutral atoms) from the depositing flux, but generally they result in a greatly reduced deposition rate.

The changes in vacuum coating technology have resulted in changes in vacuum technology for coating applications. Fifty years ago, vacuum technology meant “how to generate the lowest possible gas pressure,” then came the problem of dirty vacuum environments that led to the development of “clean” or “dry” vacuum systems and new pumps such as the cryopump, the turbopump, and oil-free mechanical pumps including the diaphragm pump. With the development of sputter deposition, the need was for handling inert gases while the development of reactive deposition relied on the control of the mass flow and partial pressures of reactive gases as well as the formation of uniform chemically active plasmas over large volumes and areas. The use of chemical vapor precursors in reactive deposition has injected the concept of “transit conductance” or how a vapor molecule gets from one place to another by adsorption-desorption mechanisms in contrast to the concept of equilibrium conductance for gas molecules (where there is no adsorption). Plasma decomposition of chemical vapor precursors results in the generation of nanoparticles. These nanoparticles can affect the operation of the vacuum pumps.

The branches of the development tree in vacuum coating have gone in many directions. The branches in the future will obviously go to plasma physics and chemistry, chemical vapor precursors, high ionization of depositing species, energetic atomic and molecular deposition processes, and higher pressures. New technologies, equipment, and applications have still to be developed in this vibrant vacuum coating industry.

Donald M. Mattox is the SVC Bulletin Editor and Technical Director. Contact him at donmattox@svc.org with your views on the TechCon, the Bulletin, or any other issue.
Preparation of a stimulating and attractive program of the 49th Annual Technical Conference for the SVC is in full swing. All indications are that we will have another full program. The entire team is working hard to put together the program much earlier this year, and it is going very well. Expect another mixture of core and new topics. However, the success of the TechCon will once again be based on the contributed presentations. We are looking for numerous subjects of interest to the SVC community; we are happy to see the large number of abstracts being submitted at this time. If you still plan to submit an abstract, use the SVC Web Site at http://www.svc.org/TC/TC06/CFP06Sessions.html. You may also want to contact the respective Sessions Chairs to discuss the appropriateness for individual sessions (please see the list on page 9).

The next TechCon's program will continue the success from previous years, and as always we are attempting a few variations. These variations have been introduced by the organizing committee in order to satisfy the suggestions and expectations of different groups of participants. The backbone of the program is formed by the well-established Technical Sessions, including Optical Coating, Large Area Coating, Plasma Processing, Process Control & Instrumentation, Vacuum Web Coating, Tribological & Decorative Coating, Emerging Technologies, and Smart Materials sessions, featuring original presentations from industry, academia, government agencies, and national laboratories. The most important subjects of each session will be introduced by carefully chosen invited speakers. Individual descriptions of each session can be found on the following pages. Besides the more traditional oral presentations, we also expect an increasing interest in the poster session, with its annual award for the best poster. As in previous years, a number of presentations will be made by students who are supported through the SVC Student Sponsorship Program.

In order to emphasize hot topics in the area of vacuum coatings and especially those of particular interest to the broad SVC community, the 2006 program will feature two Joint Sessions, namely on Biomedical and Pharmaceutical Applications of Vacuum Processes and Coatings and on Flexible Electronics, each of which will be introduced by invited talks of highly recognized researchers (see pages 6 and 9). Most recent developments will be presented in the already well-appreciated Heuréka! Post-Deadline Session, while the latest developments in equipment and services will be presented in the Innovators Showcase.

We are happy to announce that the 2006 technical program will be kicked off on Monday, April 24, 2006, by the keynote lecture of Dr. Pascal Goldschmidt, Duke University, who will introduce, from the "end user's standpoint," the very attractive topic of "Challenges in Materials Science for Applications in Medicine" (see page 8). Another area of special interest is the Donald M. Mattox Tutorial Program with well-chosen lunch-time lectures. In 2006, our invited tutorial speakers are Professor Kazuhiro Hane, Tohoku University, Japan, who will discuss the "Advances in Micro- and Nanotechnology with the Emphasis on MEMS and MOEMS," and Dr. Lewis Bass, Lewis Bass International, who will introduce the "Manufacturing Aspects of Integrating Vacuum Processes and Coatings, that underlines the importance of this multidisciplinary field for the SVC community and that is co-organized jointly by the Chairs of the Tribological, Optical, Plasma, Process Control, Smart Materials and Emerging Technologies TACs. Highlights of the program will be a series of invited talks covering different aspects of fabricating, testing, and applying of biomedical film systems. Invited speakers include:

- Professor Roland Hauriet of the Materials Science and Technology Institute (EMPA), Duebendorf, Switzerland, who will speak on "Hard and Protective Coatings for Medical Implants and Medical Devices."
- Professor Richard Gilbert of MIT, who will discuss the "Use of Photocatalytic Thin Films for Respiratory Life Support."
- Dr. Andrew Fisk of Greatbatch Inc., Columbia, MD, who will introduce the "Manufacuring Aspects of Integrating Vacuum Processes and Coatings with Pmcakers and Other Cardiovascular Devices."

The invited talks will be complemented by oral and poster presentations covering numerous other subjects such as surface treatment for enhanced biocompatibility, surface cleaning and sterilization, corrosion resistance and accelerated screening tests, optical coatings for biomedical devices and instrumentation, surface and interface analysis of biomedical systems, porous and micro/nanstructured films, bio-MEMS, photocatalytic effects, patterning, packaging, adhesion and interface phenomena, compatibility with FDA standards, equipment scale-up, and process economics.

We expect to have a very attractive program to which you are warmly invited to contribute. We look forward to meeting you at the SVC 2006 TechCon.

Session Co-Chairs are Ludvik Martinu, École Polytechnique, Canada, (lmartinu@polymtl.ca) and Peter Martin, Pacific Northwest National Laboratory, (peter.martin@pnnl.gov), in collaboration with the TAC Chairs of Tribological & Decorative Coating, Optical Coating, Plasma Processing, Process Control and Instrumentation, Smart Materials, and Emerging Technologies.
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Major advances in medicine and medical treatments have been possible thanks to the application of new and novel materials with tailored functional properties suitable for medical practice, including diagnostics as well as clinical treatments. In his presentation, Dr. Pascal J. Goldschmidt will discuss the achievements in medicine that are closely related to the performance of materials surfaces and coatings that provide specific functions related to different aspects ranging from biocompatibility, cell recognition and sterilization to macro- and micro-systems used as implants, diagnostics elements, and therapeutic components. He will illustrate the main trends in this field by numerous examples of diseases and medical treatment procedures in which the materials performance plays an important role.

Dr. Pascal Goldschmidt is widely considered one of the nation’s leading physician-scientists in the field of cardiovascular medicine. As a researcher, he is a leader in cardiovascular genomics and has discovered gene variants that contribute to heart attacks. He also uncovered several cellular pathways that cause human disease and has unveiled a novel mechanism that explains the effect of aging on the risk for cardiovascular disease.

Dr. Goldschmidt is Chairman of the Department of Medicine at Duke University. He was appointed to lead the Cardiology Division at Duke in 2000 — this is an internationally recognized cardiology program. He is the Edward S. Orgain Professor of Cardiology and Director of the Center for Cardiovascular Genetics. In addition to his clinical role as a cardiologist, Dr. Goldschmidt is also a leading cardiovascular investigator. He has initiated research at Duke University in genomics and cell biology applied to the diagnosis and prevention of atherosclerosis.

A native of Belgium, Dr. Goldschmidt received his medical degree from the Université Libre de Bruxelles and completed residency training at Erasme Academic Hospital, Brussels, Belgium. He trained in immunology research at the Medical University of South Carolina. Dr. Goldschmidt’s training in Cardiology was at Johns Hopkins University, where he also studied Cell Biology (1988 to 1991). He became Assistant Professor and Associate Professor in Medicine-Cardiology and also Cell Biology and Anatomy (1991 to 1997), and directed the Johns Hopkins’ Henry Ciccarone Center for the Prevention of Heart Diseases, Thrombosis Center, and Bernard Vascular Biology Laboratory. After winning numerous prestigious awards, he was then recruited as Director of the Ohio State University’s Heart and Lung Research Institute and as Director of the Cardiology Division before being recruited by Duke University.
Joint Session on Processes, Materials, and Coating Systems for Flexible Electronics

The fact that the Joint Session on Processes, Materials, and Coating Systems for Flexible Electronics is already in the fifth consecutive year at the SVC Annual Technical Conference, shows that it is an important, unifying event at the TechCon; this underlines the importance of both scientific and technological advances in this field. The main focus of this session will be on the most important breakthroughs and trends in recent years in the areas of display technologies, energy control and energy conversion technologies (including organic photovoltaics, large area organic solar cells, glazings, and others) and security devices. In 2006, the program will specifically include new concepts of film materials and film fabrication techniques, evaluation of the film system performance, process and materials control and metrology, mechanical properties and long-term stability of the film systems, plasma-based technologies and processes, as well as general questions related to the economics of the processes and applications. Many of these aspects, documented by the latest research results, will be presented by our invited speaker, Professor Carlos Da Silva, Université de Montréal, Canada, in his talk entitled, “Progress and Challenges in Understanding and Controlling Electronic Processes in Plastic Electronic Devices.”

Based on the extreme interest witnessed in previous years, the number of presentations received, and the large attendance at the 2005 Joint Session, we expect again a very successful and stimulating program.

Session organizers are Ric Shimshock, MLD Technologies LLC, (ricshimshock4mld@aol.com), Assistant Program Chair, and Ludvik Martinu, École Polytechnique, Canada, (lmartinu@polymtl.ca), General Program Chair, working in close collaboration with the TAC Chairs of Vacuum Web Coating, Optical Coating, Large Area Coating, and Plasma Processing.

Continued on page 10
SMART MATERIALS SYMPOSIUM

Whether you are a thin film designer or a manufacturer, you cannot afford to miss our exciting “Smart Materials Symposium” organized as part of the SVC Annual Technical Conference. This Symposium will cover numerous hot topics dealing with new materials and systems, most often stimulated by advanced applications and economic trends.

Dr. Frederick Krebs (Danish Polymer Institute, RISØ) has organized a session devoted to organic photovoltaics and conductive polymers. With the sharp increase in World oil prices, serious money is being invested in the solar cell area. This includes new materials, deposition, and manufacturing schemes including roll-to-roll (R2R) processes. Our tentative program so far includes the following invited speakers: (i) Remi de Bettignies of CEA-Saclay, France, will give a talk entitled, “Investigation by RBS and Accelerated Lifetime Measurement of Aging Process in Organic Photovoltaic Solar Cells,” (ii) Monica Lira-Cantu of Spain will discuss “Oxide-polymer Hybrid Solar Cells,” (iii) Matteo Biancardo of Italy-Denmark (RISØ) will speak on “Extremely Thin Absorber Solar Cells,” and (iv) Eva Bundgaard of Denmark (RISØ) will discuss the subject “Low Band Gap Polymers for Solar Cells.”

We will have an opportunity to listen to a number of other exciting invited speakers in the Smart Materials Symposium. Prof. Claes Granqvist has invited Prof. Yuzo Shigesato of Aoyama Gakuin University, Japan, who has studied the PVD of functional oxide thin films, including various kinds of transparent conductors and electrochromic materials. His talk is entitled “The Sputter Deposition of High-quality Thermochromic VO2 Films for Smart Windows.” Dr. Bernd Szyzska has invited Dr. Christian-Herbert Fischer (HMI, Germany) to give a talk on the “Ion Layer Gas Reaction (ILGAR) Process.” The talk will cover the development of sequential chemical methods for the deposition of inorganic metal oxides and sulfides.

Also, don’t miss our Technology Forum Breakfast Roundtable Sessions on Organic Photovoltaics and Smart Materials.

We welcome you to join and contribute to our sessions on Smart Materials.

Carl M. Lampert, Star Science (cmilstar@sonic.net) is the Chair of the Smart Materials TAC. Ric Shimshock, MLD Technologies, (ricshimshock4mld@aol.com); Claes G. Granqvist, Uppsala University, Sweden, (claes-goran.granqvist@angstrom.uu.se); Bernd Szyzska, Fraunhofer Institute for Surface Engineering and Thin Films, Germany, (szyzska@ist.fhg.de); and Frederik Krebs, RISO National Laboratory, Denmark (frederik.krebs@risoe.dk), are the Assistant TAC Chairs.

PLASMA PROCESSING

The ability of plasmas to provide both energetic and chemically active species make them a unique enabling tool in the production of surfaces with a wide range of applications including hard and functional coatings, microelectronics, and biomaterials. The rapidly evolving demand for high-performance materials requires a fundamental understanding of plasma sources, plasma properties, and the subsequent plasma-surface interactions. The Plasma Processing TAC’s 2006 program will focus on the rapid advances in both fundamental and applied plasma science associated with the plasma processing industry. The sessions will feature a number of notable presentations including Professor J. Reece Roth, University of Tennessee, who will discuss his research in atmospheric pressure plasmas. Professor Gottlieb Oehrlein, University of Maryland, will discuss his work on photoresist etching. We are again organizing a special session on Plasma Processing and Sputtering Technologies (HIPIMS) that will feature a presentation by Dr. C. M. Lampert, University of Iceland, describing experimental investigations of the HIPIMS discharge.

The strength in the SVC Plasma Processing sessions has always been the diversity in content with a strong relationship between diagnostics and processing. We continue to encourage presentations in the following areas:

- Plasma diagnostics (Langmuir probes, mass spectrometry, residual gas analysis, laser spectroscopy, optical emission/absorption spectroscopy)
- Film growth characterization (infrared spectroscopy, electron spectroscopy)
- Plasma-based deposition and processing platforms (sputter deposition, ion plating, reactive ion etching, and plasma enhanced chemical vapor deposition)
- Atmospheric plasma processing techniques (barrier discharges, flowing plasmas)
- Novel plasma sources
- New and innovative plasma processing (plasma polymerization, nanostructures, biomaterials)
- Modeling of the plasma and plasma/surface interface

In addition to our special HIPIMS session, we are co-organizing a joint session on Bio-medical and Pharmaceutical Applications for Vacuum Processes and Coatings and a joint session on Processes, Materials, and Coating Systems for Flexible Electronics. We invite you to discuss your research in any of the areas listed and look forward to another great conference.

Scott Walton, US Naval Research Laboratory (swalton@ccsri.navy.mil), is the Plasma Processing TAC Chair. Arutjun Ehiasarian, Sheffield Hallam University (aehiasarian@shu.ac.uk), and Falk Milde, VON ARDENNE Analagentechnik GmbH (milde.falk@vonardenne.biz), are the Assistant TAC chairs.

VACUUM WEB COATING

As you would expect, the Web TAC membership has been actively seeking presentations to make the next TechCon one to remember. We are planning to acquire enough presentations for three sessions on vacuum web coating. We will also actively participate in the Joint Session on Processes, Materials and Coating Systems for Flexible Electronics.

The subjects that have provided the focus for the sessions are as follows:

- Barrier and active packaging
- Medical and biomedical sensors
- Security coatings and devices
- Energy, including insulation, solar cells, batteries, heaters, fuel cells
- Optical and optoelectronics
- Transparent conductive, anti-reflecting, display films
- Thin film magnetics
- Materials for web coating, including boats and films
- Substrates, handling and quality control, contamination, defects and cleaning
- Process control and quality control/equipment advances
- Competing technologies to vacuum web coating (e.g., inkjet technology in flexible electronics, atmospheric plasma)

Barrier packaging, energy, transparent films, and substrates have been the most active topics, and we expect to have some good presentations to stimulate the audience. Particular mention should be given to the topics of substrates. We all use them; few of us have control of the manufacturing process and up-stream processing and so have to manage the substrate we receive. For many of the newer applications, the substrate is nowhere near good enough to use directly, and so we all have some strategy to compensate for this. We are seeking presentations that look at the contamination problems and some of these recovery strategies.

One of the Invited Speakers will be Dr. Olsson from Umicore who will be presenting the topic “Thin Films Engineering of Indium Tin Oxide and Other Metal-Based Materials.” There are many concerns over the availability of indium, and there is great interest to find an alternative, which makes this talk so timely.

We look forward to interesting and stimulating sessions at the next TechCon.

Charles A. Bishop, C.A. Consulting Ltd. (CABishopConsulting@cabuk1.co.uk) is the Vacuum Web Co-Chair; Peter Moulds, Ursa International Corporation (ursaintl@sbcglobal.net) is the Vacuum Web TAC Co-Chair (outgoing); and Gregory Tullo, SE Associates, Inc. (gtullo@seassociatesinc.com) is the Vacuum Web TAC Co-Chair (incoming).
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**SVC TechCon Highlights**

**Heuréka! Post-Deadline Recent Developments Session**

This SVC session enables authors to present their newest results, developments, and discoveries, well after the official conference abstract deadline. The session is run independently of all other TechCon sessions in the evening on Monday and Tuesday of the conference.

This is not a “catch-all” session for late papers. The number of presentations is limited and is only focused on recent developments of importance to the vacuum coating community.

The abstract deadline is March 1, 2006 in order to guarantee inclusion in the Final Program. If you have questions contact Láď Bárdos, Uppsala University at ladislavbardos@angstrom.uu.se or Hana Baránková, Uppsala University at hana.barankova@angstrom.uu.se

**Optical Coating**

We are now preparing an interesting and diverse program on optical coating for the 2006 TechCon. The focus will be on recent trends and advances in the areas of new optical film systems and devices, new optical coating materials, and film fabrication techniques. The majority of contributions will cover three important aspects of optical coating technology: optical film metrology, process control and monitoring, and different advanced applications. Special emphasis will be placed on novel approaches for coatings for military and aerospace applications, optical instrumentation, optoelectronics and photonics, as well as displays, optical data processing, biophotonics, and telecommunications. The program will reflect the driving forces for further advancement of this field, including biomedicine and biosensors, energy control, automobile, aerospace, architecture, and other applications.

There will be a number of invited presentations that tend to take a big-picture approach, setting the stage for the contributed presentations that follow. For example, Jim Heaney of Swales Aerospace, will talk about “Optical Thin Film Applications in the Space Environment,” Rommel Noufi of NREL will introduce the subject of “State of the Art of Polycrystalline Thin Film Cadmium-Indium-Gallium-Selenium Solar Cells,” while Aram Amassian, of the École Polytechnique, Canada, will present an important aspect of “The Role of Ion Bombardment during the Growth of Optical Films and Tailoring of Interfaces Studied by in situ Real Time Ellipsometry and Monte-Carlo Simulations.”

Other presentations will describe recent research on optical films for biomedical, astronomical, and security applications. Film properties are always an important consideration, the most critical being optical, but other important functional characteristics such as mechanical and chemical protection, electrical conductivity, and gas and vapor permeability will be discussed. Work will be presented that combines optical design with microstructural features tailored on the nanometer and micrometer scales, with special film properties such as optical nonlinearity and engineered band gap. Evaluation of film stability and integrity in harsh physical and chemical environments and their compatibility with novel substrate materials (including organic polymers) will be addressed.

Please also note that work on optical films will be included in the joint sessions on Flexible Electronics and Biomedical Applications. We hope that you will be able to participate in this exciting optical coating program, and we look forward to meeting you and all the contributors in Washington, DC.

Bryant Hichwa, Sonoma State University, (bryant.hichwa@sonoma.edu) and Ian Stevenson, Denton Vacuum, LLC, (istevenson@dentonvacuum.com) Co-Chair the Optical Coatings TAC. George Dobrowolski, National Research Council of Canada (retired) (dobrowolski@magma.ca), is the Assistant Chair.

**TechCon Workshop**

“**Trends and Challenges in Optical Coatings**”

Join us for an open discussion relating to challenges that face those in the optical coating industry. A panel of engineering and management experts within our field will discuss issues. Then we will brainstorm on potential solutions related to training the workforce, career advancement, capital expenditures, equipment updating, measurement, materials, potential new business areas and more.

Anonymous questions for the panel are welcome. Send them to the moderator, Jennifer Kruschwitz at jen.K@optilayer.com by April 1, 2006.

**Tribological & Decorative Coating**

The origins of tribological coatings are found back in tool applications from several decades ago. New technologies have been developed in order to accomplish higher cutting speeds and longer tool life. We are happy to present Martin Weber of the new Tribological Coatings Fraunhofer-Institut für Schicht und Oberflächentechnik in Braunschweig (Germany) as an invited speaker for the 2006 SVC Tribological & Decorative Coating sessions. His presentation will deal with new coating systems for forming tools.

In the last 10 to 15 years, the use of tribological coatings on components (especially moving engine parts in automotive applications) have become increasingly important, and expectations are that the market of component coatings will exceed the market for tools in the coming years.

Today, many high-volume applications for automotive components are already in industrial use in batch systems. The use of in-line systems integrated in the automotive manufacturing industry in comparison to high-volume batch systems is a topic of special interest.

Besides this, researchers are working on developments of new, often nanostructured, coatings and combinations of different technologies (hybrid technologies) for different application fields of coatings. Especially in Europe, environmental laws drive the development of new coating applica-
and Medical Devices.”

The market for PVD coating applications in these fields has grown significantly over the last 10 years and has reached maturity.

Completely different applications of corrosion-resistant coatings can be found in coating systems for aerospace and power generation systems, where erosion/corrosion resistance and thermal barriers are playing an important role.

New techniques developed for coatings in the above-mentioned fields are of particular interest to our TAC. Besides the aforementioned application fields, the TAC for Tribological & Decorative Coatings also is a very suitable platform for special applications for anti-wear protective tribological coatings, such as coatings for gun barrels, copy machines, and extrusion devices, as well as other generally used applications of coatings in plastic injection molding.

Another type of special tribological coatings has emerged in the last decade. These are biomedical applications of coatings such as in joint replacement implants, stents, and surgical tools. For this growing field, the importance is emphasized by the participation of the Tribological & Decorative Coating TAC Chair. Roel Tietema, Hauzer Techno Coating bv, The Netherlands (rtietema@hauzer.nl), is the Tribological and Decorative Coating TAC Chair. Gary Doll, Timken Research (gary.doll@timken.com), and Jolanta Klemberg-Sapieha, École Polytechnique, Canada, (jjsapieha@polymtl.ca) are the Assistant Chairs.

Large Area Coating

Sessions at the 2006 SVC TechCon in Washington, DC, will include invited presentations in technology, product, and market areas that will be of great interest to the large area coating community.

Victor Veerasamy of Guardian Industries will open one of our sessions with a presentation on “Thin Film Applications in Space Environment.” In this presentation, Victor will discuss how large area linear ion beam technology can be combined with sputtering to yield innovative new coatings with exciting performance properties, including temperability.

Frederick Wallin of AFG Industries will open another of our sessions with a presentation on “The Growth and Future for Large Area Architectural Coatings.” This discussion will be a review and forecast of large area coaters...
SVC TechCon Highlights

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and coating applications for the residential and commercial markets in North America and globally. Performance and aesthetic trends and conflicts will be reviewed with an eye towards the development of new coatings to meet future architectural, building code, and energy policy requirements.

Brad Austin of Viracon will open another of our sessions with a presentation on “What Architects Want from Large Area Coatings.” Although architects are not often the direct customers for large area coatings, they do design and specify coated glass systems for commercial buildings. It is vitally important that architects understand the capabilities of the latest coatings being designed in our field, and it is just as vital that we understand their needs and challenges so we can respond with coatings and coated glass systems that meet their ongoing and future requirements.

The Large Area TAC requests presentations for the 2006 TechCon in Washington, D.C., in areas that will complement and extend the topics of these invited papers. The Call for Papers recently issued requests for abstracts addressing the following topics—but as always, topics of interest are not limited to the following:

- Advances in high-rate coating processes, target materials, and equipment for sputtering and other large area deposition technologies
- Improvement in the uniformity, yield, and economics of large area coating processes
- New coatings and advances in coatings, particularly in heat-treatable and bendable coatings, easy-clean coatings, thermal control, antireflection, mirror, conductive, barrier and other coatings for architectural, automotive, and other applications
- Sensor and electronic applications suitable for incorporation into large area coatings
- Preparation and characterization of glass surfaces for coating
- Reverse engineering, online monitoring, and defect analysis of coatings
- Coatings and processes for non-glass substrates

Michael Andraeason, VACUUM COATING Technologies, Inc. (Michael.Andraes@vacuum.com) is the Large Area Coating TAC Chair and Johannes Strimpfel, VON ARDENNE Anlagentechnik GmbH (strimpfel.johannes@vonardenne.de) is the Assistant Chair.

PROCESS CONTROL & INSTRUMENTATION

The process controls and instrumentation used to make thin film coatings are constantly changing. New materials, coatings, and end-products require new techniques and instruments to create them. Even when the product isn’t changing, competitive demands are constantly pushing coaters to produce the same films at lower cost. The SVC Process Control & Instrumentation (PCI) TAC is a forum for all of these issues, where solutions to these challenges are shared with others who face the same problems.

This year, we will lead off the PCI session with the invited talk, “An Overview of Thin Film Monitoring and Control Technologies,” by Dr. C. (Larry) Lu, of C. Lu Laboratories. Larry will review techniques used to control thin film deposition, including the quartz crystal microbalance, mass spectrometer, electron impact emission spectrometer, spectroscopic ellipsometer, and atomic absorption spectrometer. His presentation will explore theory of operation, calibration, and factors that affect the measurement, such as material specificity, deposition rate and thickness, installation, maintenance, and vacuum/process environment issues. The presentation will conclude with a discussion of the advantages and limitations of these techniques for various thin film coating applications.

Recent TechCon PCI TAC sessions have included:

- Multi-gas multi-zone reactive sputtering control techniques
- Power supply arc handling in DC- and RF-based plasma processes
- Computer modeling of sputter equipment to facilitate lower cost tool and process development
- Diagnostics methods for coating of powder particles in a magnetron plasma
- Pole pieces insertions in target for NiCr Magnetron sputtering: influence on plasma and coating properties
- An optical sensor for real-time in-situ endpoint monitoring during dry etching of III-V multi-stack layers
- Index of refraction measurements for control of thin film density
- Spectroscopic ellipsometry and plasma diagnostic techniques
- Statistical process control
- Comparisons of various pumps in coating applications
- Calibration and operator training in maintaining process quality
- Process regulation in dual magnetron sputtered optical coatings
- Gas control in reactive sputtering
- Atomic adsorption spectroscopy as a process monitor
- Multi-point crystal sensor monitoring
- Overview of sputtering techniques and power supplies

The PCI TAC is interested in developments in production improvements, and any new approaches in the control of vacuum coating processes. If you’ve made improvements to your coating process, share your innovations with the rest of us by presenting your work at the next SVC TechCon, or plan to attend and take home some practical solutions to the problems you face every day.

J. Grant Armstrong, Carbery Technologies, (J.GrantA@carberytech.com) and Dave Chamberlain, MKS Instruments (dave.chamberlain@mksinst.com) are the Process Control & Instrumentation TAC Co-Chairs.

EMERGING TECHNOLOGIES

The Emerging Technologies (ET) sessions at the SVC TechCons always represent a very important forum for presentation of new technologies, results, and trends in both vacuum and non-vacuum coating. The program of the ET session is usually broader in comparison with other specialized sessions because it brings together different technologies and applications.

The ET session in Washington, D.C., 2006 will be focused on developments in new technologies and new trends in surface processing and coating. These are reflected in special topics of interest listed in the Call for Papers for the ET session:

- High-density plasma sources and processes
- Hybrid technologies
- Plasma sputtering
- Large area PECVD and large area microwave, and RF plasmas
- Cold atmospheric and subatmospheric plasma applications for surface treatment and PECVD
- Pulsed laser deposition (PLD)
- Fuel cell related technologies
- Nanotechnology: processing at nanoscale, nanoparticles and nanostructures, nanocomposites, nanopaints, and selective nanostructure growth
- Structure, surface, and interface engineering: multilayers, dispersed systems, and superlattices
- Unconventional structures in hard and decorative coatings
- Photocatalytic coatings and devices
- Organic coatings
- Coatings for space applications, energy and data storage, and communications
- Coatings for thin film batteries and active RF identification
- Coatings for biomedical applications, and biocompatible and anti-allergic coatings

This long list certainly will be extended by presentations from other areas bringing modern approaches in the coating and surface treatments.

The invited speaker in the ET session will be Eiji Kusano from the Advanced Materials Science Center, Kanazawa Institute of Technology, Japan. His presentation, “Modification of Film Structure in Pulsed and Inductively-Coupled Plasma-Assisted Sputtering,” will be devoted to the role of energetic ion flux on the microstructural properties of coatings.

We expect many exciting innovations, technical solutions, findings, results, and ideas in coating technology to be presented in the ET session to inspire attendees from both industry and research. We look forward to you joining us at the SVC TechCon in Washington, DC, next year.

Hana Baránková, Uppsala University (Hana.Barankova@Angstrom.uu.se), and Ladislav Bárdos, Uppsala University, (Ladislav.Bardos@Angstrom.uu.se) are the Emerging Technologies TAC Co-Chairs.
Technology Forum Breakfast Topics

In these facilitator-led forums, experts are available to answer your questions and discuss your concerns in an informal environment. These topics will be offered on either the Tuesday or Wednesday morning breakfast sessions. See the Preliminary Program for more details.

Tribological Coatings- Allan Matthews, University of Sheffield, United Kingdom
Tribological coatings are applied to surfaces by PVD processes to improve wear resistance and increase lubrication. Recent developments in multilayered and nanostructured coatings are advancing this technology. Using these structures, it is possible to combine high hardness and relatively low elastic modulus. These developments will be discussed along with individual applications of tribological coatings.

Plasma Processing and Biomaterials- Paul Gagnon, Corning Inc.
Plasma processing is an important role in many biomaterial applications. Plasma is used for enhancing adhesion properties or for changing the surface chemistry or morphology for cellular and chemical attachment to manufacture the latest drugs or the latest biosensor. Biomaterial applications include polymeric, ceramic, metallic and composite substrates. Bioprocess is involved with the next generation of new products. Bring your questions and problems and let’s discuss these intriguing applications.

Optical Monitoring and Process Control- Ric Shimshock, MLD Technologies LLC
Process control is critical in large area and web optical coating manufacturing processes. Real time optical monitoring of the coating being deposited is needed to control optical properties, film thickness, and thickness uniformity across the web. Feedback systems from various sensors to process control equipment are critical. Please stop by and discuss your interests and problems.

Optical Design- H. Angus Macleod, Thin Film Center, Inc.
Beam Splitter Coatings, wavelength division multiplexing, ultrafast applications, decorative coatings, glare reduction, and energy saving are just some of the currently important areas of applications for optical coatings. Coating designs range from more than one hundred layers to just one or two. In spite of advanced computer programs, optical coating design still involves skill, experience, and understanding. The emphasis in the forum will be on understanding design approaches and design methods.

Magnetron Sputtering- David Glocker, Isoflux Incorporated
Magnetron sputtering is widely used in industrial applications, from the rotating cylinders found in large area coaters to hollow cathode sources used in microelectronics. Magnetrons can be built in many configurations, and this session will explore some of the design opportunities and constraints. If you have an application, or if you would simply like to talk about what’s possible with magnetron sputtering, be sure to attend this session.

Emerging Technologies- Hana Baránková, Uppsala University, Sweden
New processes, hybrid process combinations, and new plasma sources are being developed and becoming available. What are the parameters and what are the limits of these new technologies? Learn about these new systems or share your experience and problems and their solutions.

Photovoltaics (PV) Investigations- Frederik Krebs, RISØ National Laboratory, Denmark
With the price of energy skyrocketing - investigations into alternate sources of supply such as Photovoltaics is multiplying rapidly. From Conducting Polymers, Nanotechnology, Quantum Dots and Printing Techniques, new efforts are underway to capture the power of the sun. Roll-to-Roll (R2R) processing is a key aspect of many of these proposed manufacturing schemes. Bring your questions and interest to this Technology Forum Breakfast table on an exciting new area for networking and discussion.

N- and P-type Transparent Conductive Coatings- Clark Bright, 3M Company
Transparent conductive coatings have numerous applications in flat panel displays and electronic devices. New applications on plastics are particularly exciting. All aspects of producing, characterizing, and using these coatings will be discussed.

Process Modeling- Bernd Szyzska, Fraunhofer Institute for Surface Engineering and Thin Films (IST), Germany
Process modeling continues to expand and find wider applications. Predictive models for mass transport, uniformity and film growth are becoming more accessible to users and more user-friendly. Effective use of these tools can help machine designers and process development engineers resolve issues early on.

High-Power Impulse Magnetron Sputtering (HIPIMS) - Arutiu Papken Ehasarian, Sheffield Hallam University, United Kingdom
HIPIMS is an exciting new process offering the possibility of engineering specific film properties. Come learn about this new technology and discuss the status and promise of this process.

The Technology Forum Breakfast Coordinator is Ric Shimshock, MLD Technologies LLC (ricshimshock4mld@aol.com).

Win a $200 Cash Award for the Best Poster!

For the past two years the SVC has awarded $200 for the Best Poster presentation. The popularity of this session has steadily grown since it is an excellent way to present your work in a relaxed question and answer format.

Once again, the Program Committee welcomes poster presentations on subjects of technical interest for inclusion in the Best Poster Contest at the 2006 TechCon. Abstracts must be submitted using the On-line Abstract Submission process at www.svc.org. A manuscript is required for review at the TechCon for the entry to be eligible to receive the award.

Each presenter will be provided one side of an 8 ft. by 4 ft. poster board for display of text and graphics describing the work. Poster presenters will arrange their display Monday morning, April 24, and will be required to be available at their posters to answer questions from 4:30 p.m. until 7:00 p.m. that same day. Posters will remain on display during the Exhibit Open Hours on Monday and Tuesday.

Submit your abstract today!
The SVC TechCon brings new customers your way.

This two day, one-of-a-kind forum during the annual TechCon is an excellent opportunity for exhibitors to showcase their latest innovations in vacuum coating and related technologies. The Annual SVC Technical Conference and Exhibit is always a unique and memorable event. The flexible schedule of events allows exhibitors, their customers, short-course attendees, and TechCon registrants to make the most of their conference experience. This show has sold out for the last ten years.

Exhibitor profiles are included in the *TechCon Exhibit Guide* that is mailed by first class mail to thousands of potential TechCon attendees about five weeks prior to the TechCon. Advertising in this *Guide* is a powerful way to reach the vacuum coating user. The *Guide* and the Exhibitor profiles remain on the SVC Web Site until the end of the calendar year.

**New! SVC is expanding all breaks to allow TechCon registrants more time to visit our exhibitors.**

The Exhibit Halls are also home to the Poster Session, Internet Café, Beer Blast, Networking Dinner Reception and Exhibitor Lunch. The *2006 Exhibit Prospectus* is online at the SVC Web Site, www.svc.org. Register early to secure the best booth position.

If you have questions about the Exhibit, contact the SVC Exhibit Committee Chair, Cathi Baker, Advanced Energy Industries, Inc. at 970/407-6498 or cathi.baker@aei.com, or call the SVC Administrative Office at 505/856-7188.

**INNOVATORS SHOWCASE**

The SVC Innovators Showcase (formerly called the Vendor Session) is an ideal venue to introduce new ideas, processes, products, and services to a focused and sophisticated international audience. Established with an unabashedly commercial foundation, the Showcase allows presenters to address an audience that wants to hear what you have to say. This approach is particularly effective when the presentation dovetails with your company’s participation in the SVC Exhibit. Exhibitors participating in the Innovators Showcase become more visible to prospective customers.

Presentations are limited to 10 minutes, including questions, and can be made on any topic related to the vacuum coating industry. The registration fee is waived for Innovators Showcase presenters.

Abstracts are required for acceptance into the Innovators Showcase. Abstracts must be submitted by February 15 to guarantee inclusion in the *Final Program*. Submission guidelines are available at www.svc.org.

Frank Zimone, Denton Vacuum, LLC, (fzimone@dentonvacuum.com), is the Innovators Showcase Chair.

**CALL FOR SPONSORS!**

Please sponsor a refreshment break, the Beer Blast, or the Internet Café. Sponsors are widely recognized in all SVC publications, including the *Final Program*, *Bulletin*, *TechCon Exhibit Guide*, Web Site, and on signage at the TechCon.

For more information, visit the SVC Web Site at www.svc.org.
At SVC, one of the main focus areas is Education. We offer various conduits to whet your appetite for learning in the fields that are pertinent to SVC's mission. These various forms of learning opportunities are available to suit everyone's needs.

Courses at TechCon 2006: The TechCon in Washington, DC, April 22-27, brings you some of the tried and tested and always popular courses and instructors. In addition, there will be some new offerings. Professor Joe Greene, whose courses on sputter deposition have always attracted a large audience, is scheduled to teach a new course on “Reactive Sputter Deposition.” Another new course on “Introduction to Ellipsometry” will be presented by James N. Hilfiker of J. A. Woollam Co. Inc. Other new courses on atomic layer epitaxy, thin film metrology, etc., are in the process of being organized. Please stay tuned.

Short descriptions of the courses are always available on the SVC Web Site and in the Call for Papers. Now, read all about it! More detailed descriptions of all the courses have been added to the SVC Web Site at http://www.svc.org/EP/EP_CourseDescription.html to help you choose the course of your liking.

Courses at Your Work Place: Unable to come to the TechCon? No problem! We can bring the course to you. A large number of on-site courses are available. So far this year we have taught 12 on-site courses. Please contact Vivienne Mattox at viviennemattox@svc.org or check out the web site http://www.svc.org/EP/EP_OnsitePrograms.html.

Distant Learning: Want to learn at your own pace and at a place of your own choice? SVC, in collaboration with the University of Delaware, offers a web-based course on “Vapor Deposition Processes.” You receive a CD of the course material and online access to the instructor for two weeks. This course is offered twice a year, in June and in December. Please check the web site http://www.svc.org/EP/EP_LongDistance.html.

We always keep our ears open for suggestions regarding new courses or any matter dealing with SVC and education. One such suggestion last year was to explore China as a market for SVC courses. We are looking for ways to penetrate that market. Let us know if you have any suggestions. We are seeking people who would like to develop SVC courses in both English and Chinese. Are you interested? Please contact me at the following address.

Ismat Shah, University of Delaware (ismat@udel.edu), is the SVC Education Committee Chair, and Vasgen Shamamian, Dow Corning Corporation (v.shamamian@dowcorning.com), is the Assistant Chair.
SVC Committee Reports

SVC Awards Committee

Awards Nominations Needed

The Awards Committee of the SVC is soliciting nominations from SVC members for both the Nathaniel H. Sugerman Memorial Award and the Mentor Awards. These awards are our way of recognizing those who have helped make vacuum technology and the Society so successful. Visit the SVC Web Site at www.svc.org for a complete list of previous winners and their contributions.

The Sugerman Award commemorates the enduring efforts of Nat Sugerman in founding, nurturing, and supporting the Society of Vacuum Coaters. It recognizes significant contributions in one or more of the following areas:

- Distinguished service to the SVC
- Outstanding technical achievement
- Noteworthy educational contributions to the vacuum industry
- Creative innovation in the development of a product or process pertaining to the vacuum industry

The Mentor Awards recognize people who have made or are making significant contributions to the SVC and/or the industry by their example or guidance, including one-on-one and one-on-many interactions. Both types of awards may be given posthumously.

Please send nominations to Dave Glocker, the Awards Committee Chair, at david@isofluxinc.com. In your e-mail please include which award the nomination is for, the nominee’s affiliation, contact information, and a one- or two-sentence statement about the nominee’s accomplishments. Letters of support are helpful and are encouraged (two for the Sugerman Award and one for the Mentor Awards).

Announcement of the awards will be made at the Annual Business Meeting of the Society at the TechCon in April 2006. Nominations can be made by SVC members only and are due by December 16, 2005. Members of the Awards Committee as well as contractors working for the SVC are ineligible.

David Glocker, Isoflux Incorporated (isofluxhc@aol.com) is the SVC Awards Committee Chair.

SVC Future Sites Committee

Convention Centers: Good for SVC?

A question often asked by our members is “why don’t we go to my favorite city?” Most of the time, the answer is simply that there is not a hotel large enough to accommodate our group.

For some years, convention centers in these cities have been considered for the conference. Only smaller centers connected to a hotel are considered so that we can keep the “all under one roof” feeling of the conference. 2007 will be our first time in a hotel and convention center and our first time in Louisville, Kentucky. Two first time experiences in our 50th anniversary year.

The decision to try a convention center was not as simple as picking one with a connection to a hotel and smaller facilities. We are used to dealing with a hotel, which involves one contract, one liaison person, and known expenses in the negotiations. Choosing a convention center means another contract and several more people to deal with, in addition to many more expenses to negotiate. Our meeting planner and Executive Director, Vivienne Mattox, CMP, has spent many more hours trying to obtain the best deal for SVC.

Now that we have acquired experience in dealing with convention centers, it was disappointing to learn that the overbuilding of centers in many cities is not looked upon as a good thing by everyone. Cities desperate for more revenue are allocating huge sums of money to build or enlarge their convention centers and build a new headquarter hotel which is attached. However, established hotels in the area, already suffering from too many unbooked rooms, are fighting back and saying “No” to the new hotels/convention centers. It appeared that this worked in our favor because they are offering good deals to fill up the convention centers. We will have to see how this works out in the future. Fortunately, more hotels with larger convention centers are still being built so we will have more choices.

Knowing what questions to ask while inspecting a convention center is different than when inspecting a hotel. For instance, when we use hotel rooms for meetings, lunches etc., carpeting and the linens are provided. There is often a charge for them in convention centers, as well as a charge for water, and room setup changes. We never think about trash removal in hotels, but this is usually an extra expense in convention centers. Heating, lighting, and air conditioning during exhibit set-up and tear-down is included at hotels but not necessarily in convention centers. A big part of negotiating hotel contracts revolves around the SVC spending money on food and beverage. When we split our functions between a convention center and a hotel, we split the dollars spent also. This means we have less to bargain with on both contracts.

One big advantage we have at hotels is that our group uses so much of the meeting space that we do not have to contend with other groups during our conference. There is usually only meeting space left for very small groups. The downside is that we have to account for more room nights (attendees booking rooms) to get all of the space. This is why it is very important for our attendees to book within the room block at the host hotel. Convention centers may have two or even three groups using the facilities at the same time. This is when the layout of the center becomes very important. Some convention centers that are attractive in both price and facilities have not been able to provide space that keeps our group close and other groups away.

The opinions and thoughts of our members...
are always important to the SVC committees. So if you are bemoaning the fact that your favorite site or city is never chosen, we ask you to keep in mind the multitude of factors that have to be considered when choosing a site.

Pamela Diesing, Sage Industrial Sales, Inc., (sage4sales@aol.com) is the SVC Future Sites Committee Chair.

SVC History Committee

Historical Papers Section of the SVC Web Site

A new Historical Paper has been placed on the SVC Web Site titled, "A Discussion on 'The Making of Reflecting Surfaces.'" (SVC Web Site/History/Historical Papers.)

This is the published record (Fleetwood Press) of a meeting of the Physical Society of London and the Optical Society held on Nov. 26, 1920. The papers are on both chemical formation of reflecting coatings and vacuum coating, including plasma cleaning. One paper, "A Bibliography of the More Important Papers on the Construction and Nature of Reflecting Surfaces," by R. Kanthack, covers the history of making reflecting surfaces back to 1798. (An original copy of this document was loaned by Don Mattox.)

Anyone having unique historical material on vacuum coating is invited to loan it to SVC so that we can place it on the Web Site. There is particular interest in obtaining a copy of the Swiss Patent #223344 (Jan. 4, 1943) on optical coatings.

50th Anniversary Publication to Document History

To commemorate the SVC's 50th Anniversary in 2007, the creation of a publication that will be titled "50 Years of the Society of Vacuum Coaters" is planned. The publication will be in two parts. The first part will be the organizational history of SVC, and the second part will be vacuum coating technology as seen by SVC Technical Advisory Committees (TACs.)

The History Committee would appreciate the help of anyone who would like to be on the editorial team for the publication. We would welcome volunteers from each Technical Advisory Committee to serve as Associate Editors for their appropriate technical subject.

Attention Old-Timers!

We need your input. The retirees of our vacuum coating community are the individuals who can help the History Committee and 50th Anniversary Committee fill in the blanks on the early history of SVC.

If you are willing to contribute to the publication, please send your comments and contributions to Don Mattox at donmattox@svc.org, or call him at 505/856-7188.

Donald M. Mattox, SVC Technical Director (donmattox@svc.org), is Chair of the History Committee. Ric Shimshock, MLD Technologies LLC (ricshimshock4mld@aol.com), and Dale Morton, Denton Vacuum (retired) (dmorton@dentonvacuum.com), are the Assistant Chairs of the History Committee.

SVC Scholarship Program

The SVC Foundation Scholarship Program, now in its fourth year of existence, is gearing up to consider applicants for the 2006 Scholarship Awards.

Since its beginning, the Scholarship Program was intended to attract new talent to the vacuum coating industry. This includes university students (both at undergraduate and graduate level) as well as students at technical colleges and trade schools.

Another goal is to encourage individuals who are already working in the vacuum coating industry or in a related field, to seek additional education. For example, a vacuum coating technician aspiring to become an engineer, would be eligible to apply for the SVC Scholarship, as long as he is enrolled at an accredited post-secondary institution.

The SVC Foundation and its scholarship program are funded by contributions from individuals and businesses interested in promoting vacuum coating technology. The Foundation's initial goal is to raise $250,000 to endow the fund.

The SVC is funding the Foundation administrative costs, so all donations received go directly to support the Foundation, including the scholarship program. The SVC has established a fund to match contributions received for the Foundation.

To receive additional information about the scholarship program go to the SVC Web Site at www.svc.org/SF/SVCFoundationSchol.html. The deadline for receipt of applications is January 31, 2006.

To make a pledge to the SVC Foundation, please contact the SVC Administrative Office at 505/856-7188 or by email at svcinfo@svc.org.

Paolo Raugei, Galileo Vacuum Systems, (praugei@att.net), is the SVC Scholarship Committee Chair.
Short-Pulse Effects in Optical Coatings

Angus Macleod
Thin Film Center Inc, Tucson, AZ

Introduction
So far in these tutorials we have been discussing phenomena that can be described as “steady state.” In most applications of optical coatings, we can safely assume that the illumination began a sufficiently long time before, and will continue for a sufficiently long time after, any measurement of the coating response. Transient effects can be completely ignored. However, within the last decade or so, transient effects in optical coatings have become of great significance in two important application areas: ultra-fast optics and optical communication. Both of these areas involve pulses of light so short as to be of the same order of magnitude as the response time of the coating.

What is the response time of an optical coating? We can form a very rough idea by considering the speed of light. This is 299,792,458 nanometers per femtosecond (fs). For simplicity, assume a wavelength of 1000 nm and a reflector of 25 quarterwave layers. The total optical thickness traversed by light that penetrates to the final layer and then returns to the front surface will be 12500 nm, taking a time of 12500/299.79 fs, that is 41.7 fs. Ultra-fast pulse lengths less than 10 fs are regularly achieved. Much longer response times are involved in an optical cavity, the basic structure for a narrow-band filter. To reach a steady-state condition, the cavity must fill with energy. The process needs many reflections back and forth between the cavity surfaces. We can take the number of round-trip traversals of the cavity as roughly equal to the resolving power of the filter. Optical communication filters may have resolving powers greater than 2000 at 1550nm. In first-order (halfwave thick cavity), this implies a total path of 3 x 10^12 nm and a response time of 10 picoseconds (ps). This is of the same order as the pulse length in high-capacity channels (100 Gb/s is 1 bit in 10 ps).

These simple calculations indicate that a problem exists. To deal with the problem demands a greater level of understanding of transient effects. Fortunately, the effects are linear. In our first tutorial, we introduced the property of linear systems that allows the coating response to be expressed in terms of a spectrum of harmonic components. We can use this approach, but, this time, we must include the relationship between the various components.

Properties of the Basic Pulse
A simple light pulse consists of a short burst of light of a particular frequency. The profile is similar to that shown in Figure 1. It can be thought of as consisting of a monochromatic wave, the “carrier,” modulated by a more slowly varying function, the “envelope”, that falls to zero on either side of a peak. The pulse depicted in Figure 1 has an envelope consisting of a Gaussian function, and this is a quite normal arrangement. Sometimes, light pulses will be severely limited laterally. Such limitation will introduce also an angular spectrum that must be included in the calculations. In order to avoid such complications, we will assume that the pulse has sufficient lateral width for any angular spectrum to be negligible.

If we were able to look closely at the pulse as it propagates, we would see that the envelope generally moves at a velocity that is different, and usually slower, than that of the carrier. We have special terms for these velocities. For historical reasons, the carrier velocity is known as the “phase velocity,” and the envelope velocity as the “group velocity.”

Let us represent the pulse in the usual way as a continuous spectrum of harmonic waves. The frequency spectrum will have a Gaussian shape (an important property of Gaussian pulses) centered on the carrier frequency. The longer the pulse, the narrower will be the frequency distribution. To reconstitute the pulse we add all the harmonic components, but in this summation we must take account of their phases. The components are all oscillating between positive and negative. At distances or times far from the pulse, the resultant field will be zero. This implies a jumbling of the phases so that as many components show a positive as a negative field. Consequently, their fields will cancel. At the pulse, the component fields must reinforce, implying a similar phase. In fact, the pulse peak will correspond to an exact phase coincidence. Figure 2 attempts to illustrate this. The electric field of the spectral components at a particular instant in terms both of distance and frequency is shown as a set of contours. At the peak of the pulse, the components must have all their phases exactly in step. If the coincidence occurs exactly at the peak of the carrier, then the peak of pulse and carrier will coincide. If not, the peaks will be displaced with respect to each other.

Figure 1. Profile of a light pulse consisting of a carrier of constant frequency modulated by a Gaussian function. The horizontal axis may be distance or time.

Figure 2. Representation of the frequency spectrum of the pulse showing the various components at a particular instant as a function both of frequency and of physical distance along the pulse propagation direction. Electric field is indicated as a set of colored zones. The red areas correspond to the peaks and the blue areas to the troughs of electric field. At the peak of the pulse there is a coincidence of the phases of all the components. Here it is shown coinciding with a peak in each component, but it may occur at any point in the cycle and varies as the pulse propagates. \( \omega_0 \) is the angular frequency of the carrier.
We can think of this diagram in two ways. It shows the results of the decomposition of the pulse, but it also shows how to find the pulse position if we know the details of the harmonic components. Let us think of the diagram in the second way. We assume that the pulse peak and the carrier peak at zero time occur at zero distance. Then we can write the condition for the phase coincidence as:

\[ \omega_0 t - \kappa_0 z = \omega t - \kappa z \]

Equation 1

where the left-hand side is the phase of the carrier, and the right-hand side is the phase of any of the harmonic components. \( \kappa \) denotes the wavenumber, \( 2\pi n/\lambda \). The values of \( z \) and \( t \) where this coincidence occurs are related through the velocity of the pulse. We can write in a slightly different way:

\[ \omega_0 t - \kappa_0 z = \left( \omega_0 + \Delta \omega \right) t - \left( \kappa_0 + \Delta \kappa \right) z \]

Equation 2

which simplifies to:

\[ \Delta \omega \cdot t = \Delta \kappa \cdot z \]

Equation 3

The velocity of the pulse, the group velocity, is then distance traveled divided by time:

\[ \text{Group velocity} = \frac{z}{t} = \frac{\Delta \omega}{\Delta \kappa} = \frac{d\omega}{d\kappa} \]

Equation 4

the third equality being valid if \( \Delta \omega \) is linearly proportional to \( \Delta \kappa \). The carrier velocity, more correctly the phase velocity, is just \( \omega_0/\kappa_0 \).

**Propagation Problems**

Now let us consider a slightly more complicated situation, illustrated in Figure 3. Here the harmonic components have propagated a certain distance but are now somewhat out of step, so that the best approach to a phase coincidence is at the line illustrated, but it is certainly not perfect.

![Figure 3](image3.png)

Figure 3. Here, after the pulse has propagated a certain distance, it becomes impossible to detect an exact phase coincidence of the harmonic components. The best peak position is that shown, but the phase does not completely coincide across the components.

We can look at the distribution in a slightly different way, Figure 4. Here we have divided it into two parts: a higher frequency and a lower frequency slice. If we look at these separately we can recognize in each a much better phase coincidence than in the entire distribution. In this particular case, the lower frequency slice corresponds to a pulse that is

![Figure 4](image4.png)

Figure 4. A slightly different way of looking at the problem divides the distribution into two parts: a higher-frequency and a lower-frequency slice. Each, separately, can be considered as belonging to a different pulse (the upper delayed with respect to the lower), and each rather broader than the original. The carrier frequencies are also different.

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**re • li • a • ble**
adj consistently dependable in performance or result

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![PHPK Technologies](image5.png)

**Historic Past, Vibrant Future**
continued from page 21

particular case, the lower frequency slice corresponds to a pulse that is
rather earlier than the pulse corresponding to the upper. Also the carrier of
the early pulse has a lower frequency than that of the later, upper, pulse.
Because the frequency distribution for each pulse is half the original, the
pulses are much broader.

Of course the two pulses are amalgamated into one single pulse, and
the transition is a little smoother than suggested in Figure 4. The composite
pulse is thus much broader than the original, and the carrier changes
frequency through its width. The pulse is said to be broadened and chirped.
A chirped pulse is illustrated in Figure 5. The frequency is shown as rising
through the pulse. It can also fall, and depends on the curvature of the
counters shown in Figure 4.

(7). Note that the terms are proportional to
the distortion we have mentioned and must be individually zero to satisfy
condition. The other terms, involving the higher derivatives, however, cause
this more complicated case. Now

We can extend the analysis in equations (1) through (4) to deal with
more complicated case. Now \( \kappa \) is no longer a linear function of \( \omega \).
Without specifying the functional relationship exactly, we can use a Taylor
expansion to denote how \( \kappa \) varies in the vicinity of \( \omega_0 \):

\[
\kappa = \kappa_0 + \frac{d\kappa}{d\omega} \Delta \omega + \frac{d^2\kappa}{d\omega^2} \frac{(\Delta \omega)^2}{2} + \frac{d^3\kappa}{d\omega^3} \frac{(\Delta \omega)^3}{6} + \ldots
\]

If we substitute (5) in (1), we obtain for the phase coincidence condition:

\[
\omega_0 t - \kappa_0 z = (\omega_0 + \Delta \omega) t - \left( \kappa_0 + \frac{d\kappa}{d\omega} \Delta \omega + \frac{d^2\kappa}{d\omega^2} \frac{(\Delta \omega)^2}{2} + \frac{d^3\kappa}{d\omega^3} \frac{(\Delta \omega)^3}{6} + \ldots \right) z
\]

and with some rearrangement:

\[
0 = \left( t - \frac{d\kappa}{d\omega} \cdot z \right) \Delta \omega - \frac{d^2\kappa}{d\omega^2} \frac{(\Delta \omega)^2}{2} - \frac{d^3\kappa}{d\omega^3} \frac{(\Delta \omega)^3}{6} + \ldots
\]

First term in the right-hand side is the original group velocity
condition. The other terms, involving the higher derivatives, however, cause
the distortion we have mentioned and must be individually zero to satisfy
(7). Note that the terms are proportional to \( z \), and so the problem worsens
with the pulse propagation distance. The names for the parameters are:

\[
\frac{d^2\kappa}{d\omega^2} = \text{Group Velocity Dispersion (GVD)}
\]

\[
\frac{d^3\kappa}{d\omega^3} = \text{Third Order Dispersion (TOD)}
\]

Group Velocity Dispersion has units of time/length and Third Order
Dispersion of time/length.

The wavenumber \( \kappa \) is given by:

\[
\kappa = \frac{2\pi n}{\lambda} = \frac{n\omega}{c}
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Figure 5. A representation of a chirped pulse.

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and with some rearrangement:

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\]

Group Velocity Dispersion has units of time/length and Third Order
Dispersion of time/length.

The wavenumber \( \kappa \) is given by:

\[
\kappa = \frac{2\pi n}{\lambda} = \frac{n\omega}{c}
\]
where \( dω/dκ \) is the Group Velocity, and where the derivative expressions may be used if they are constant over the spectrum. The time for the pulse to reach point \( z \), is lengthened by a positive value of \(-dϕ/dω\), which has units of time. Because this term is delaying the pulse, it is known as the "group delay." In transmission, the group delay will include the time delay in traversing the gap BD shown in Figure 6.

The phase shift, especially in reflection, is susceptible to design. A negative value of group delay is equivalent to a pulse advance, implying that a coating might be designed to reflect a pulse before it actually reaches the reflecting surface. Common sense is a good guide in such matters. It will be found impossible to design a passive interference coating that, over the pulse spectrum, has both sufficiently high reflectance and sufficiently large negative group delay, for any appreciable effect of this kind.

Like the wavenumber \( κ \), the phase shift, \( ϕ \), is rarely a linear function of \( ω \). Exactly as in equations (5) through (7), we expand \( ϕ \) in a Taylor series.

\[
ω_0 t - κ_0 z = (ω_0 + Δω) t - \left( \frac{dκ}{dω} Δω + \frac{d^2κ}{dω^2} \frac{(Δω)^2}{2} + \frac{d^3κ}{dω^3} \frac{(Δω)^3}{6} + \cdots \right) z + \left( \frac{dϕ}{dω} Δω + \frac{d^2ϕ}{dω^2} \frac{(Δω)^2}{2} + \frac{d^3ϕ}{dω^3} \frac{(Δω)^3}{6} + \cdots \right)
\]

Equation 14

i.e.,

\[
0 = \left( t - \frac{dκ}{dω} \cdot z \right) Δω - \left( \frac{d^2κ}{dω^2} \cdot z - \frac{d^2ϕ}{dω^2} \right) \frac{(Δω)^2}{2} - \left( \frac{d^3κ}{dω^3} \cdot z - \frac{d^3ϕ}{dω^3} \right) \frac{(Δω)^3}{6} + \cdots
\]

Equation 15

The new derivatives are named:

\[
-\frac{d^2ϕ}{dω^2} = \text{Group Delay Dispersion (GDD)}
\]

\[
-\frac{d^3ϕ}{dω^3} = \text{Third Order Dispersion (TOD)}
\]

Equation 16

Group Delay Dispersion has units of \( \text{time}^2 \) and Third Order Dispersion has units of \( \text{time}^3 \).

The form of equation 15 shows the possibility of canceling dispersive effects of propagation by suitably designed coatings. This is an important current area of coating design.

Reflecting systems are more readily designed to have a given group delay dispersion or third order dispersion than transmitting coatings. Femtosecond pulses have broad frequency spectra and, to avoid pulse distortion, a reflector must be correspondingly broad. Some wavelengths will be reflected deep in the coating, while others will penetrate only to a shallow depth. The depth of penetration is related to the group delay. By adjusting this depth as a function of frequency, or wavelength, the slope of the group delay, and hence the group delay dispersion, can be adjusted. For a constant group delay dispersion, the depth should vary smoothly, increasing more rapidly toward one of the edges of the spectrum. This gives a tapered structure to the coating, usually referred to as a "chirp," by analogy with the chirped pulse. A difference in the tapering of high index with respect to low index layers gives what is known as a "double chirp," and such structures have been found to give advantages in design. The limitation on the theoretical performance is essentially the maximum thickness of coating that can be manufactured.

Pulses can be artificially chirped by passing them through an electro-optical modulator. A coating can not detect any difference between a pulse that has been broadened and chirped by group velocity dispersion, and one that has just been artificially chirped. Thus, a correctly designed coating...
can cancel the notional group velocity dispersion to remove the artificial chirping and in the process shorten the pulse. This is one very important and successful way of arriving at very short ultra-fast pulses. Manufacturing tolerances are so exceptionally tight that it is rare to achieve exactly the required performance in a single coating. Fortunately, the effects are additive, and a short cascade of selected reflectors can even out the errors.

In the field of optical communication, much use is made of narrow-band transmission filters. Their usual structure is a series of coupled, tuned cavities. In transmission, a single tuned cavity structure presents a positive group delay with a typical resonance shape, while a two-cavity filter exhibits the form of a coupled resonance, sometimes with a pronounced dip in the center, as in Figure 7. The narrower the width of the response, the greater is the delay, and, in telecom applications, it reaches significant picosecond levels. The typical shapes for the group delay dispersion curves are also indicated in Figure 7. Although the fine details of the variations of group delay and group delay dispersion can be modified in design, it is virtually impossible to change their magnitude radically. For example, the dip in the center of the double-cavity design can be reduced, which in turn reduces the group delay dispersion variation in the center of the pass band. Provided the bandwidth of the signal channel can be kept within the central region of such a filter, all will be well.

For a dispersion compensating component, the variable depth technique used in the femtosecond region is inappropriate because of the enormous coating thicknesses that would be required. Fortunately we are dealing with a quite limited spectral region. We still use reflecting structures, but they now consist primarily of a resonator of the type shown in Figure 7, deposited over a reflector. The shape of the reflection characteristics are similar to the transmission ones, and compensation becomes a matter of matching different parts of the characteristics of the various components.

Further Reading

The literature is extensive. Here is a selection consisting of a text book together with some important papers whose authors have been responsible for major advances.


For further information, contact Angus Macleod at angus@thinfilmcenter.com.
Ideally, vacuum chambers should have only permanent seals and no temporary or demountable seals. In some applications, only permanent seals are used, such as the “tip-off” or “pinch-off” seals in glass chambers such as electron tubes. Other permanent seals are fusion welds, metal pinch-offs, glass fusion joints, etc. Generally, vacuum coating systems use temporary or demountable seals to allow joining of components and access for cleaning and reaching or removing fixturing. Some of these seals are “broken” more often than others. Early vacuum seals used melted wax and rubber stops.

The most common seal is the elastomeric “O-ring” seal. This continuous seal is typically retained in a groove of a specific geometry. When deformed, the O-ring exhibits a force (pressure) on surfaces in contact with the elastomer. The O-ring size and groove are designed so that when there is surface-to-surface contact, the O-ring is deformed to give a predetermined pressure and area on a surface. The “sealing surfaces” should be smooth and free of scratches. The wrong diameter O-ring seal can give poor sealing (vacuum leaks).

There are a number of elastomer materials that can be used as a sealing material. These include neoprene, Buna-N, silicone, Viton™, and Kelrez™. Materials such as Teflon™ that “take-a-set” on deformation are generally not suitable for elastomeric sealing because the sealing pressure decreases with time. The cost of a seal can vary widely with material, processing, and inspection.

Factors that determine the seal material to be used are: cost (original and replacement), temperature to which the seal must operate, outgassing rate (if applicable), chemical resistance (if applicable), tendency to produce particulates (if applicable), lifetime, etc. Inspection of seals may include X-raying to make sure that there are no metal inclusions that can cut the material on deformation. Seal packaging can include bake-out and cleaning before packaging. Seals should be of a size to fit the O-ring groove without stretching or compressing. If it is necessary to make an elastomer seal, use O-ring material of the proper diameter, cut to length, and glue together using SuperGlue™ (cyanoacrylate).

Viton™ is a common vacuum sealing material. It has a low outgassing rate, low gas and vapor permeation rate, fair chemical resistance, and good thermal tolerance (to 200°C). Unfortunately, the term Viton™ can be attributed to rubber blends that include Viton™ material, so care must be used to specify 100% Viton™ rubber for vacuum seals. Other elastomeric materials such as Kelrez™ are more chemically resistant than is Viton™ but cost a great deal more.

Elastomer seals meet their greatest challenge in their use on access seals that are opened and closed often. The elastomeric properties are cycled many times, but in addition they are subjected to many forms of abuse. Because they stick out above the surface of the groove, they are subjected to scrapes and cuts when the seal is open. When the system is cleaned, particles may be deposited on the O-ring and in the groove, particularly at the bottom of the chamber. When the seal is closed, these particulates wear and cut the O-ring material. This is one advantage to having the O-ring groove in the door rather than the main part of the chamber (tank).

A disadvantage to having the O-ring groove in the door and the flat sealing surface on the main part of the tank is that the flat sealing surface is more likely to be scratched as operators work in the chamber or fixtures are moved in and out. Scratches can lead to vacuum leaks, and on large surfaces they are difficult and costly to re-machine! It may pay to have a method of protecting the sealing surface while work is going on in the chamber. Small scratches in a sealing surface can be removed by careful polishing and leaving any scratches parallel to the axis of the O-ring.

There is the perpetual argument as to whether to grease the O-ring or to use it dry. When being deformed, an O-ring slides over the surface. A little vacuum grease lubricates this sliding and fills in small scratches on the sealing surfaces. A disadvantage is that the grease accumulates debris, and the O-ring needs to be cleaned and re-greased occasionally. This in turn has the advantage in that this can be an opportunity to inspect the O-ring for cuts and abrasion. If you are using a mild steel vacuum tank, the grease helps keep the sealing surfaces from rusting. Take your pick!

To clean an O-ring, I take a paper towel, wet it with acetone, and wrap the towel around the O-ring. I put my hand around the towel and apply a little pressure as I pull the O-ring through the towel. After I do this several times, I put vacuum grease on my fingers and draw the O-ring through my fingers. Then, using dry towels, I try to wipe away as much grease as possible. Clean the groove using a towel and acetone. Do not twist the O-ring as you put it back in the groove. Many O-rings have a ridge around the circumference from the molding operation. Use this as a guide to not twist the O-ring.

A small notch leading down to the base of the O-ring groove on the atmospheric side aids in removing the O-ring with a small plastic tool without the danger of cutting the O-ring. A series of such notches around the seal allows better helium leak detection process if necessary.

Large seals are often held closed by atmospheric pressure. Smaller seals may be held together by bolts or clamps. The threads of the bolts should be coated with a dry lubricant such as molybdenum disulfide or coated with silver, a low shear metal. If the seal is large with many bolts, the bolts should be tightened in a pattern such as not to warp the flange. The surfaces should be metal-to-metal, and all bolts tightened to the same torque.

Some seals are not demounted (broken) very often. They may be elastomeric seals, but there are other types that may be of interest. These include the metal shear (knife-edge) seals (copper), and metal deformation seals (copper, indium, aluminum, gold, and silver). These seals are not reusable. There is also a spring metal “C” seal where the compression of the spring metal from top to bottom supplies the sealing force. These are often coated with silver. These types of seals have very low outgassing and low gas/vapor permeation rates.

Inflatable elastomeric seals can be used when the sealing surfaces are warped and don’t provide uniform pressure when “closed.” These seals are like bicycle tubes and are inflated under pressure. When there is a gap between the sealing surfaces, this technique will exert a uniform pressure everywhere on the sealing surfaces no matter what the gap spacing (within limits). When used to retrofit a chamber, spacers must be used to give a minimum gap between the sealing surfaces (i.e. not metal-to-metal) and to hold the seal in place.

If a seal is not metal-to-metal and not bolted, each part of the chamber should be grounded if a plasma is to be used in the chamber. Electrically isolated surfaces in contact with a plasma can assume a sheath potential that is different than other parts of the system. This can affect plasma uniformity. Some O-ring sealed systems use copper/beryllium contacting spring “fingers” to ensure electrical contact between sections when closed.
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MDC employs advanced (TIG) welding techniques

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ABSTRACT

Electron beam physical vapor deposition (EB-PVD) is a well established large area coating technology. Reactive EB-PVD allows the deposition of some important compounds. Although EB-PVD is a superior coating technology regarding highest deposition rates, its successful industrial application in some cases depends on a further improvement of layer properties. Plasma activated EB-PVD is a process combination which allows to increase density, hardness, refractive index and other properties of the coatings.

One possibility of plasma activation concerning the electron beam evaporation process is the ignition of a spotless arc discharge on the EB heated evaporant which is well known as Spotless arc Activated Deposition process (SAD process). This process has been extended for the first time to large area dimensions. Reactive large area SAD of titanium dioxide has been carried out at deposition rates of up to 70 nm/s.

Results of these investigations will be presented. The technological capacity of reactive large area SAD will be considered with regard to advantageous applications. Coating costs will be compared with other coating technologies.

INTRODUCTION

Within the last decades, industrial applications of large area EB-PVD have obtained more and more importance. At the beginning, EB-PVD of aluminum on strip steel was introduced as corrosion protection. Meanwhile, various metallic and oxide layer stacks on strip steel are applied in the car production industries in order to improve corrosion protection, welding ability, wear resistance and adhesion of organic top coatings. Double sided copper coating of strip steel by EB-PVD is industrially introduced with the aim to obtain solderable surfaces for pipe soldering of high pressure pipes of refrigerator systems and brake lines [1]. Recently, aluminum coatings on steel based alloys are applied in the production of metal supported catalytic converters. High resistance coatings like SiO$_2$ on stainless steel, are applied as protection layers between the back contact of thin film solar cells and the bearing flexible metallic substrate [2]. In the same application molybdenum coating is commonly used [3]. EB-PVD of nickel on steel is promising with regard to the production of batteries [4]. In the last few years the variety of metal strip substrates has been enlarged, especially by aluminum and copper strips. The current coating tasks include, for instance, optical coatings as reflectance enhancing layer stacks on aluminum strip and solar absorbing layers on copper or aluminum strip [5]. The reflectance enhancing layer stack consists of a highly reflecting aluminum layer and a transparent low index high index layer pair from silicon dioxide and titanium dioxide. All single layers can be deposited by EB-PVD. The layer thickness deviations of EB-PVD processes can be kept below 3% [6]. This short overview demonstrates that, meanwhile, more and more substrate layer systems are in the focus of the finishing industries which are going to extend their diversity of finished products by means of high rate (reactive) EB-PVD.

Nevertheless, in some cases the layer properties of coatings deposited by EB-PVD have to be improved in order to guarantee special advantages of the finished product. Therefore, possibilities of ion assistance and of plasma activation of the evaporation process have become increasingly interesting.

Ion assisted reactive EB-PVD makes use of an ion source in order to enhance the reactivity of the process gas which is added to an evaporation process with the aim of stoichiometry stabilization of evaporated compounds as oxides [7]. Linear anode layer ion sources with sufficient high linear homogeneity of the ion density are now available.

The other way to improve layer properties by plasma activation makes use of a plasma generating equipment acting in addition to the electron beam evaporation process. The hollow cathode activated evaporation process applies a variety of circular symmetric hollow cathodes in order to combine the vapor cloud by hollow cathode arc discharges, thus generating the plasma [8]. In the spotless arc activated deposition process (SAD), an anode near the crucible is applied in order to ignite a spotless arc onto the electron beam heated evaporant in the crucible. The EB heated evaporant acts as cathode [9,10]. Figure 1 shows the principle arrangement of crucible and the SAD anode. The system is completed by a gas manifold which is used in the case of a reactive process guidance.

The plasma activation by means of SAD has some advantages:

a) High plasma densities with an ionization degree of up to 60% can be achieved [11].

b) The additional equipment in the process surrounding of the EB evaporator is less expensive than other plasma generation tools.

c) The position of the arc on the evaporant coincides with the location of the electron beam generated vapor source. Therefore the activated vapor distribution may be similar to the initial EB vapor distribution.

One limitation regarding the applicability of the SAD process is that only some refractory metals are useful to form out a diffuse arc on the evaporant. One of the most interesting metals which renders possible SAD is titanium.

This contribution will deal with the application of SAD concerning the coating of titanium and its compounds and will answer the following questions:

a) Which coating rates can be achieved today using SAD as deposition technique regarding titanium and its components of titanium dioxide and titanium nitride?

b) Which layer properties can be achieved by means of SAD?

c) Is it possible to extend the SAD process to large area dimensions?
EXPERIMENTAL

The investigations which were carried out consisted of two stages. The experiments of the first stage were carried out in the R&D coater of the project partner which is applied for metal strip and metal sheet coating. Figure 2 shows a scheme of the technological equipment which was used in order to carry out the first experimental part of the program. Steel strips having a width of 260 mm and steel sheets having a width of 500 mm were coated by SAD with titanium and titanium compounds as free-span deposition. The substrate pre-treatment included sputter etching and, in some cases, additional preheating.

The experiments of the second stage were carried out in the own pilot coater FOBA600 which is applied in order to coat thin metal foils and plastic webs. This coater is equipped with a very large movable and water cooled copper crucible. Figure 3 shows the scheme of the coater. In this coater, steel foils up to a thickness of 0.1 mm having a width of 600 mm can be coated as well as plastic web. The substrates are guided through the deposition zone by a cooling drum. In both coaters the electron beam from the slanting EB-gun is bent by a magnetic field into the water cooled copper crucible which was filled with titanium metal. The anode is arranged at the long edge of the crucible crosswise to the substrate transportation.

The first stage of the experiments dealt with the principle study of long-term stability of the SAD process. The coating rates which lead to full stoichiometrical compounds and essential layer properties had been evaluated. In the case of reactive SAD, oxygen and nitrogen was added to the process by a gas manifold. Table 1 summarizes important details and experimental parameters. The layer thickness has been measured by several methods as GDOES and ellipsometry. The latter was used in order to evaluate optical constants as well. The hardness was measured by means of nanoindentation.

In the second stage of experiments the extension of SAD to a large area process was tested. The movable titanium filled crucible had a length of 1200 mm. A jumping beam, writing two filled ellipses with an EB-power of 100 kW, was used to generate a double source. The single source areas had a distance to each other of 500 mm. The current of the diffuse arc amounted to 1000 A. The non-reactive SAD process was carried out at a process pressure of 1 x10^{-4} mbar.

RESULTS

The SAD process showed remarkable stability. Reactive SAD of titanium compounds had been carried out under constant conditions over a period of more than two hours. The diffuse arc generated a dense plasma on the evaporant and was steered by the hottest

<table>
<thead>
<tr>
<th>Feature</th>
<th>Titanium</th>
<th>Titanium oxide</th>
<th>Titanium nitride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crucible</td>
<td>Cooled copper</td>
<td>Cooled copper</td>
<td>Cooled copper</td>
</tr>
<tr>
<td>Evaporant</td>
<td>Titanium</td>
<td>Titanium</td>
<td>Titanium</td>
</tr>
<tr>
<td>EB acc. voltage</td>
<td>40 kV</td>
<td>40 kV</td>
<td>40 kV</td>
</tr>
<tr>
<td>EB power</td>
<td>60 kW</td>
<td>25...60 kW</td>
<td>17 kW</td>
</tr>
<tr>
<td>Process gas</td>
<td>/</td>
<td>Oxygen</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>Gas flow</td>
<td>/</td>
<td>3000... 5000 sccm</td>
<td>2000 sccm</td>
</tr>
<tr>
<td>Process pressure</td>
<td>2 · 10^4 mbar</td>
<td>2.3 · 10^4 mbar</td>
<td>2 · 10^4 mbar</td>
</tr>
<tr>
<td>Arc current</td>
<td>200 A</td>
<td>200...300 A</td>
<td>100 A</td>
</tr>
<tr>
<td>Bias voltage</td>
<td>/</td>
<td>130 V pulsed DC</td>
<td>100 V pulsed DC</td>
</tr>
</tbody>
</table>

Table 1. Important Details and Experimental Parameters (First Stage of Experiments)
zone on the titanium melt which was generated by the electron beam impingement. Because of the vapor source near plasma generation, the layer thickness distribution across the strip showed no significant deviations from the distribution of an evaporation process without plasma. Table 2 displays the basic coating results regarding titanium and its compounds. The ignition of the plasma enhances the reactivity of the vapor. Therefore, the layers of titanium compounds achieved full stoichiometry at considerable rates. The hardness of the titanium nitride layer is comparable with layers coated by cathodic arc evaporation. But the SAD process is working without emission of droplets.

The refractive index of titanium dioxide depends on the coating rate, the arc current, the oxygen flow and the substrate temperature. Figure 4 shows the best achieved refractive indices of titanium dioxide coatings which were deposited at various deposition rates. The arc current had an amount of 200 A and 300 A, respectively. No substrate heating was carried out. Higher coating rates require a higher arc current on the one hand and a more complex parameter fitting on the other in order to achieve high indices.

The second stage of experiments referred to the problem of upscaling the SAD process to large area dimensions. Therefore, two EB heated zones with a distance of 500 mm were generated and then the diffuse arc was ignited. Figure 5 shows the SAD process concerning the described two sources.

Large area coating requires extended vapor source distributions in order to achieve an extended layer thickness homogeneity. From the technical point of view, a double source distribution is the simplest distribution [12]. Therefore, the case of two overheated vapor sources has special importance regarding the study of large area extension of SAD. The experiment showed that the ignited diffuse arc has been split and reaches both overheated regions on the evaporant from one and the same anode.

### Table 2. Coatings Results

<table>
<thead>
<tr>
<th>Feature</th>
<th>Titanium</th>
<th>Titanium dioxide</th>
<th>Titanium nitride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating rate</td>
<td>400 nm/s</td>
<td>40...70 nm/s</td>
<td>30 nm/s</td>
</tr>
<tr>
<td>Dynamic dep. Rate</td>
<td>5500 nm x m/min</td>
<td>550...960 nm x m/min</td>
<td>420 nm x m/min</td>
</tr>
<tr>
<td>Appearance</td>
<td>metallic brilliant</td>
<td>transparent</td>
<td>golden</td>
</tr>
<tr>
<td>Optical constants</td>
<td>n(550 nm) = 2.2 ... 2.45 k(550 nm) ≤ 0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>7...10 GPa</td>
<td>30 GPa</td>
<td></td>
</tr>
</tbody>
</table>

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[Image: Affordable NIR Thin-Film Analyzer]
CONCLUSIONS AND OUTLOOK

The discussed experiments have proven that titanium and its compounds can be coated by means of SAD respectively reactive SAD at high and stable rates. The dynamic deposition rate of titanium dioxide amounts to approximately 1000 nm x m/min. At this rate, high quality layers can be deposited which are well suited for instance regarding optical applications. The same rate can be achieved with more than 20 dual cylindrical magnetrons. This means that the equipment costs of SAD compared with sputtering solutions are considerably lower.

Another important fact is the possibility of substitution of expensive titanium suboxides as evaporant by low cost titanium. The price of TiO$_2$ is about 140 USD/kg. Compared with this titanium metal has a price in the order of only about 5 USD/kg. This means that the coating costs can be reduced drastically in the case of reactive SAD.

The last experiments have displayed that the SAD process can be extended to a large area technology. There are no limitations regarding substrate widths. The way into industrial applications is now open. Coatings of titanium and of its compounds are widely spread in the finishing industries. Table 3 gives an overview over some applications. In the near future industrial application of SAD can be expected in these fields.

ACKNOWLEDGMENT

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REFERENCES

Ion-Induced Effects During Bias- and Pulse-Controlled Reactive Sputtering of ITO Films

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Abstract

Research on tin doped indium oxide (ITO) has for many years been stimulated by the need to simultaneously optimize the electrical, optical and mechanical properties, and by new challenges related to the deposition onto flexible plastic substrates. In this work, we systematically studied ITO films deposited by reactive sputtering from an indium-tin alloy target. We found that additional substrate biasing, as well as pulse frequency and duty cycle, allow one to effectively control the level of stress and the crystalline structure and composition. Stress-free films possessing high transparency (>80%) and low resistivity (2 × 10^4Ω/cm) were deposited under moderate ion bombardment and medium pulse frequency. Ion-induced changes in the refractive index, extinction coefficient, and their depth profiles were revealed by spectroscopic ellipsometry and spectrophotometry. We discuss the possible mechanisms related to the modification of film properties due to ion bombardment, pulsing, and other plasma-based phenomena.

Introduction

Tin-doped indium oxide (ITO) is a highly degenerated, wide band gap, n-type semiconductor with high transmittance in the visible region and with high electrical conductivity [1, 2]. This unique combination of electrical and optical properties allows wide use of ITO films in different types of optoelectronic devices such as solar cells and flat panel displays, as well as in automotive and architectural applications (“smart” windows, etc.) (see, for example, refs. 3–5).

Different deposition techniques can be used to produce ITO coatings; this includes reactive evaporation, ion beam-assisted deposition, spray pyrolysis, chemical vapor deposition, and magnetron sputtering (MS) [1, 6]. The latter technique is most widely accepted due to good reproducibility and high film quality.

Two main approaches have been used in the MS of ITO: the sputtering targets are made either of a press mixture of In_2O_3 and SnO_2 powders or of an alloy of In and Sn metals. Metal targets are less expensive and easier to recycle; however, the film oxidation level is more difficult to control. Excess oxygen in the deposition chamber can lead to “poisoning” of the target, and reduces the deposition rate, \( r_p \). Low amounts of oxygen lead to non-transparent, metal-rich films [1, 6].

A materials’ conductivity is a product of the density of free carriers and their mobility. The carrier density in ITO is determined by two factors: (1) the concentration of donor Sn atoms (set by the target composition) and (2) the concentration of oxygen vacancies. Each of these effects leads to the contribution of electrons to the conduction band [6]. However, too low an oxygen concentration gives rise to the creation of metallic bonds and deteriorates the optical performance of ITO. Therefore, high carrier mobility is very important for achieving high conductivity without lowering the films’ optical transmission [7].

Carrier mobility depends on the microstructure of the material; vacancies, holes, pores, dislocations, and grain and phase boundaries all significantly contribute to the mobility. A traditional way to control the structure of ITO films is in-situ or post-deposition annealing at temperatures between 250 and 450°C [1, 6]; however, this method is not applicable to polymeric substrates.

Substrate biasing during film growth has been used by several groups when fabricating ITO films by sputtering [7–11]. Yang et al. [7] studied the effect of negative substrate bias, \( V_s \), on the crystal size and resistivity. They found that low negative bias (\( V_s < 50 \) V) decreases the resistivity by a factor of 2, while a higher bias reduces the crystal size, leading to an increase of electron scattering at grain boundaries. Similar results were obtained by Sujatha et al. [10] for films deposited at 370°C. They attribute lower resistivity to increased electron mobility. In addition, they also observed a decrease of tensile stress from 1.3 GPa to 0.6 GPa.

The use of mid-frequency pulsing (usually hundreds of kHz) of the DC magnetron discharge (pulsed magnetron sputtering, PMS) is another, relatively new way to control the microstructure of films [12]. This method has been successfully implemented for the deposition of AlN, TiO_2 and Al_2O_3 [12–14]. Improved film structure and density by pulsing was found for all films, as well as stabilization of the deposition process and significant reduction of arcing. Recently, new results on ITO deposition by PMS were reported, showing the effect of pulse frequency and duty cycle on film structure and stoichiometry [15–18].

In this work, we fabricated ITO films by MS, while creating an additional radiofrequency (RF) discharge in the vicinity of the substrate, with the aim of inducing ion bombardment (leading to structural changes and improvement of their characteristics). We evaluated the effect of \( V_s \) at substantially higher values (up to 600 V) compared to previously mentioned authors. We also deposited ITO films using PMS while studying the effect of pulse frequency and duty cycle on the film properties. In particular, we investigated changes in film crystallinity, surface roughness, optical and electrical characteristics, as well as mechanical properties such as hardness, elastic modulus, and stress.

Experimental Setup

ITO films were deposited by reactive DC and pulsed-DC magnetron sputtering from a 50-mm diameter indium-tin (90% In/10% Sn) alloy target using a mixture of argon (16 sccm) and oxygen (4 to 8 sccm). In the case of PMS, the magnetron was powered by the Pinnacle Plus (Advanced Energy Industries, Inc.) power supply that allows one to vary the pulse frequency (f) from 5 to 350 kHz. Corning glass slides, Si(100) wafers, and poly(ethylene-terephthalate) (PET, 100 µm thick foils) were used as substrates. They were fixed at a 150-cm diameter rotating holder, about 100 mm from the magnetron head. Negative self-bias voltage, \( V_s \), was controlled by the RF (13.56 MHz) power applied to the substrate holder.

Film conductivity was measured by the four-point method at room temperature. The optical properties (such as refractive index, \( n(\lambda) \), extinction coefficient, \( k(\lambda) \), and thickness, \( d \) of the deposited layers were determined using vacuum angle spectroscopic ellipsometry (VASE, J. A. Woollam Co) and spectrophotometry (Perkin-Elmer Lambda 19). Film thickness was also measured by step profilometry (Dektak stylus profiler).

The mechanical properties (such as hardness, \( H \), and Young’s modulus, \( E \)) were determined from the load-displacement curves (average from 10 indentations) measured by a depth-sensing indentation system.
The film’s microstructure was determined by grazing angle X-ray diffraction (XRD, Philips X’pert diffractometer) at room temperature with an angle of incidence of 0.5°. The XRD patterns were recorded using Cu-Kα (1.5406Å) radiation at 50 kV and 40 mA. The diffraction angle was scanned between 20° and 80°, and a divergence slit of 1° was used to obtain a strong enough signal for relatively short acquisition times.

**RESULTS**

**A. Effect of substrate bias**

**Film crystallinity**

Most direct evidence of the changes in the microstructure of ITO films was obtained from XRD measurements (see Fig. 1). Films deposited at no bias were amorphous, while all others present different levels of crystallinity, depending on the choice of substrate material. In the case of PET, the most pronounced crystalline structure was achieved at \( V_b = 200 \) V, while for films deposited on glass and on Si (not shown here), the diffraction peaks increased with bias, resulting in the best resolved crystalline structure for \( V_b = 600 \) V. This means that larger crystal grains are formed at high bias.

![Figure 1. XRD spectra of ITO films deposited at different values of \( V_b \) at room temperature on glass (a) and PET (b) substrates.](image)

A similar conclusion was obtained from the measurement of surface roughness (as shown in Fig. 2). A linear increase of surface roughness with bias indicates that the growth of the crystals is favored at more energetic ion bombardment conditions. This result is not very surprising, given the fact that ions are known to increase the mobility of surface atoms. However, some authors [8] found that ITO crystal size decreases at \( V_b > 50 \) V; that conclusion was not confirmed in our study.

Post-annealing at 450°C in air for one hour of the films deposited at \( V_b = 0 \) V leads to a pronounced polycrystalline structure. It does not change the crystal size for films deposited at \( V_b > 200 \) V, pointing to structural stability of these coatings.

**Optical and electrical properties**

Changes in the film microstructure due to ion bombardment are followed by a significant improvement in film transparency and conductivity (see Figs. 3 and 4). The transmission spectra (Fig. 3) revealed a gradual increase of transmission in the visible part of the spectrum. Besides restructuring, accompanied by a better-defined band gap in the UV and a sharper increase of reflectance in the near infrared (IR) regions, this effect can be attributed to a higher oxidation rate. Additional RF glow discharge formed in front of the substrate holder produces atomic oxygen close to the surface, which readily reacts with the growing film. Maniv et al. [20] noticed a similar phenomenon, that is, a significant improvement of transparency of ITO films when applying RF power to the substrate even when using a very low \( V_b \) of ~ 5 V, and hence a very moderate ion bombardment energy.

We also performed a detailed ellipsometric analysis of the films’ optical performance. Using an ellipsometric model allowing for the variation of \( n \) as a function of depth, we observed that the film homogeneity improves for films deposited at higher bias. The \( n \) depth profile becomes flat for films deposited at \( V_b = 600 \) V, while at \( V_b = 0 \) V, the \( n \) value at the top of the film was about 10% lower than that near the substrate (Fig. 5). This observation points to the development of a more porous microstructure when ITO becomes thicker.

![Figure 2. AFM measured roughness of 200-nm thick ITO films deposited on PET substrate as a function of mobility of surface atoms.](image)

The increase in film conductivity at higher \( V_b \) (Fig. 4) can be attributed to a higher electron mobility resulting from larger crystals with fewer defects. Contrary to some literature reports [7], we have not noticed any substantial increase in resistivity for high values of \( V_b \). We surmise that the main reason for this discrepancy is the different set of initial conditions; in fact, our films were less transparent and less conductive at \( V_b = 0 \) than the films described in ref. 8. However, final layers obtained at optimized deposition conditions possess very similar characteristics in both cases.

**Mechanical properties and stress**

In the third part of this work we systematically evaluated the films’ mechanical properties. For ITO deposited on Si with no bias, a low tensile stress (\( \sigma = 100 \) MPa) developed. At \( V_b = 200 \) V, near zero stress level was achieved, while higher values of \( V_b \) led to a compressive stress reaching a value of about 500 MPa) at \( V_b = 600 \) V (Fig. 6).

Higher compressive stress developed for...
higher values of \( V_b \) led to a compressive stress reaching a value of about 500 MPa) at \( V_b = 600 \text{ V} \) (Fig. 6).

Higher compressive stress developed for films deposited on PET substrates, presumably due to the thermal component of stress. Indeed, large difference between the thermal expansion coefficients for PET and ITO (60 to 80 \( \times 10^{-6} \text{ K}^{-1} \) and 6 to 8 \( \times 10^{-6} \text{ K}^{-1} \), respectively) leads to a compressive stress of 10 to 20 MPa/K when the sample cools down. Deposition temperature increases with \( V_b \), and it is estimated to reach \( \sim 100^\circ \text{ C} \) at \( V_b = 600 \text{ V} \).

No peeling or cracking was observed for the films deposited on all substrates; however, high stress levels may compromise long-term reliability of such coatings on plastics. In this respect, substrate cooling during film deposition should decrease the thermal component of stress. It should be noted that moderate ion bombardment (\( V_b < 200 \text{ V} \)) leads to a near zero or a slightly compressive stress, which is favorable for good film adhesion.

The measured values of film hardness (\( H \)) and Young's modulus (\( E \)) are reported in Table 1. We did not observe any significant effect of ion bombardment on \( E \); the value of \( E = 130 \pm 30 \text{ GPa} \) did not change even after annealing. However, \( H \) is higher for films deposited at high bias, and it does not change after annealing. In contrast, films deposited at \( V_b = 0 \text{ V} \) had \( H \) increased from 7.7 to 10.9 GPa after annealing. As discussed above, this effect is accompanied by film crystallization. In fact, this represents another proof that a compact and stable structure is achieved for films deposited under energetic ion bombardment.

### B. Effect of pulsing

Our study has clearly shown that pulsing the DC magnetron discharge has a significant influence on the properties of ITO films as well as on their deposition rate. A well-defined crystalline structure was obtained at an optimum pulse frequency \( f = 200 \text{ kHz} \) and a duty cycle \( D = 76\% \) (Fig. 7). No additional heating or biasing was applied during this process. For other pulsing parameters, the film structure remained amorphous, similar to simple DC deposited layers. When applying substrate bias during PMS deposition under optimum pulsing conditions, XRD peaks became larger, bearing witness of smaller crystal size (Fig. 8). One can also discern a shift of the peak position toward lower angles due to compressive stress, in full agreement with the stress measurement results presented in Fig. 6.

Effect of \( f \) for different \( D \) is shown in Fig. 9. As expected, a higher deposition rate was
iii) Increasing orders of magnitude when increasing well understood. At the same time, film resistivity increased by up to 6 the contrary, the decrease of the deposition rate at higher frequencies is not well understood. At the same time, film resistivity increased by up to 6 orders of magnitude when increasing f (Fig. 9b). It reached 2 \times 10^4 \ \Omega cm at f = 350 kHz for the best samples, while the optical transmission remained better than 80% (Fig. 10).

The results of PMS deposition are not very intuitive, and they require more detailed analysis. One of the components of this examination is the power brought to the surface by ions at different phases of each pulse. Recently, Bradley et al. performed such an analysis for an unbalanced magnetron configuration, where metallic Ti was sputtered in Ar [21]. They found that high-energy ions (energies up to 120 eV) are produced in the discharge during the reverse voltage overshoot phase. At 350 kHz, at their experimental conditions, there is, over the cycle, about a 50% increase in the total ion energy delivered to the substrate than when operated in DC at the same discharge power. This means that higher ion energy per deposited atom is delivered to the growing film.

In our case, one has to particularly consider the balance and energy of other species such as atomic oxygen and positive and negative oxygen ions. Investigation of such plasma-surface interactions is now in progress in our laboratory.

iv) Good quality transparent conductive ITO films were deposited by PMS at room substrate temperature. The conductivity was strongly affected by pulsing parameters. At optimized conditions (f = 300 kHz, D = 76%) we obtained a deposition rate of 0.7 nm/s, a resistivity of 2.20 \times 10^{-4} \ \Omega cm, a transparency > 80%, and a hardness of 8.4 GPa.

Table 1. Mechanical properties of ITO films deposited with and without RF bias.

<table>
<thead>
<tr>
<th>Bias (V)</th>
<th>Annealing at 400°C</th>
<th>Young's modulus (GPa)</th>
<th>Hardness (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no</td>
<td>132 ± 13</td>
<td>7.7 ± 1.5</td>
</tr>
<tr>
<td>0</td>
<td>yes</td>
<td>133 ± 30</td>
<td>10.9 ± 2.2</td>
</tr>
<tr>
<td>-600</td>
<td>no</td>
<td>133 ± 30</td>
<td>9.7 ± 2.1</td>
</tr>
<tr>
<td>-600</td>
<td>yes</td>
<td>131 ± 28</td>
<td>9.7 ± 2.2</td>
</tr>
</tbody>
</table>

Conclusion

Application of RF-induced negative bias on the substrate during DC sputter deposition of ITO films leads to several important effects:

i) The discharge created in the close vicinity of the growing film serves as an additional source of atomic oxygen, thus increasing the oxidation rate. This allows for lower values of p(O₂) and hence for a higher deposition rate.

ii) Ion bombardment induced by the RF discharge gives rise to a homogeneous refractive index depth profile and to at least partial crystallinity of ITO layers deposited at low substrate temperatures. High-quality transparent conductive films on polymer substrates were deposited this way (optical transmission > 80%, resistivity ~ 2 \times 10^4 \ \Omega cm). The hardness of such films (H ~ 10 GPa) is higher compared with layers deposited without biasing.

iii) Increasing V₂ leads to a higher compressive stress. Because the ITO films deposited at V₂ = 0 V possess tensile stress, appropriate biasing may be used for obtaining the necessary stress level (usually low compressive stress is desired).

REFERENCES

In the summer issue of the SVC News Bulletin, the advantages and disadvantages of the different ways to control the reactive sputtering process were reviewed [1]. Although partial pressure control of the reactive gas is more complex than flow control, partial pressure control provides better regulation of the composition of the reactively deposited film and higher deposition rates. A partial pressure control system consists of three basic parts: the reactive gas partial pressure sensor, the actual controller, and a fast-acting inlet valve for the reactive gas. In this article, we will explore the advantages and disadvantages of the different sensors in industrial use today for partial pressure control of the reactive gas.

The basic requirement for a reactive gas partial pressure sensor is that it must be able to generate a feedback signal that changes when the partial pressure of the reactive gas changes. This change must be detected and transmitted to the controller quickly, which usually means on the order of 100 msec or less, and there must be a good signal-to-noise ratio for the feedback signal to prevent the controller from trying to follow noise-generated changes in the signal. The actual update time needed is material dependent. For example, the feedback signal update time used during the reactive sputtering of Al2O3 must be quicker than the update time used in a TiN reactive sputtering process.

There are four different reactive gas sensors that are used today to provide a feedback signal to the partial pressure controller in a timely manner. These four are a mass spectrometer, an optical emission spectrometer (OES), the lambda sensor, and the cathode voltage value from the power supply. Each has its advantages and disadvantages.

**Mass Spectrometer.** The mass spectrometer is a very versatile instrument that can be used to track the partial pressure of many different gases that can be detected in its mass-to-charge operating range. It readily senses oxygen and nitrogen, which are the most common reactive gases. Its use as a sensor for controlling a reactive sputtering process has been known since 1984 [2]. Although there are high-pressure quadrupole mass spectrometers that can work at sputtering pressures, these high-pressure quads have a problem with oxygen. When oxygen is introduced into the chamber, the magnitudes of the detected species are reduced by as much as 30% over a 10 to 15 minute period. A reproducible process cannot work in such a variable environment. The solution to the high-pressure quad oxygen problem is to use a differentially pumped mass spectrometer with an open ion source. The interaction of the oxygen with the ionizer is virtually nonexistent, and a reliable feedback signal can be produced.

The mass spectrometer signal is generated by detecting the ion current for a particular mass-to-charge ratio, and longer current collection times produce feedback signals with better signal-to-noise ratios. However, if the collection time is too long and the feedback signal is not updated quickly enough, the controller will not be able to act fast enough to prevent poisoning of the target. Typical update times for the feedback signal from a mass spectrometer are on the order of 32 to 64 msec. Longer times can be used with some reactive processes, but 32 to 64 msec is a good range in which to operate.

Not all mass spectrometers can provide the feedback signal in a timely manner. The update time for the feedback signal should be known before one buys a mass spectrometer as the sensor for a reactive sputtering process.

The mass spectrometer, in addition to being able to track and produce a signal proportional to the partial pressure of the reactive gas, also can be used to follow changes in the sputtering atmosphere during the reactive process, which can be invaluable in detecting problems with the process. For example, when reactively sputtering TiOxNy in the presence of flow-controlled oxygen and partial pressure-controlled nitrogen, the mass spectrometer can show definitively when the oxygen traps the target in a poisoned mode [3]. The mass spectrometer also can be used to check the system prior to the start of a deposition run for the residual gases in the chamber or for leaks, and it can show the effects of outgassing during a process.

A disadvantage of the mass spectrometer used as the sensor for the reactive process is that the signal strength can drift with time, particularly in long deposition runs. However, because the ratio of the peaks stays relatively constant with time, software routines can be set up to compensate for the drift. Another disadvantage of the mass spectrometer is that it is the most expensive of the four sensors reviewed in this article due to the need for the pumping system. The cost for a differentially pumped mass spectrometer is about $30,000 to $35,000. For this author, the mass spectrometer is the preferred sensor for the reactive sputtering control system because it is the most versatile of the four and provides the most information.

**Optical Emission Spectroscopy.** Optical emission spectroscopy monitors the light generated in the sputtering process and tracks individual wavelengths, either from the sputtered species or from the reactive gas, to generate the feedback signal for the process. Although it is possible to detect specific wavelengths for oxygen and nitrogen in the sputtering plasma, the most popular OES technique used today is to monitor a specific wavelength for the sputtered material, a method introduced by Schiller et al. [4]. Nitrogen can provide a relatively strong emission line, but the emission lines for oxygen are much less intense.

Because oxygen is a frequently used reactive gas, most OES control systems track the change in the intensity of the sputtered species rather than trying to monitor the relatively weak oxygen signal. As the partial pressure of the reactive gas is increased, the intensity of the emission from the sputtered species will decrease because less target material is being sputtered as the compound forms on the target surface. Typical OES control systems determine the signal strength for the target material without the reactive gas present in the chamber, and then the operating point is set as a percent reduction of the nonreactive emission intensity.

There are several advantages to an OES control system. The OES feedback signal update time can be quite fast, on the order of 10 to 20 msec, and the cost of an OES sensor is relatively low. Detectors can be purchased for about $1,000 to $5,000, depending on whether or not a simple filter/photo diode or a spectrometer is used.

Disadvantages of an OES system are that: (1) the change in the intensity of the monitored species is a not a direct measure of the partial pressure of the reactive gas, as is the case in with a mass spectrometer; (2) the intensity of the monitored line varies with the life of the target; (3) moving substrates, particularly ferrous components, can affect the plasma and the monitored line intensity; and (4) the optics can become coated. In addition, the assumption is that the reduction in the intensity of the monitored wavelength is due to the partial pressure of the reactive gas. If there is a leak in the system or if there is outgassing, the introduction of these additional gases will also affect the monitored line intensity. Having said all this, OES is a very popular sensing technique for controlling the partial pressure of the reactive gas. In a well-maintained and a well-understood system, the above disadvantages can be overcome.

**Cathode Voltage Signal.** The cathode voltage signal, like the OES signal, is an indirect measure of the partial pressure of the reactive gas. Affinito and Parsons reported on the use of the cathode voltage signal for controlling the
reactive sputtering process in 1984 [5]. The cathode voltage changes as the partial pressure changes, but the signal monitored is the change in cathode voltage and not the actual partial pressure of the reactive gas. The magnitude of the voltage change and the direction it changes depends on the material being deposited. For example, with materials such as aluminum oxide or silicon dioxide, the voltage will decrease by over more than 100 volts from the metallic state to the poisoned state of the target. However, for materials such as titanium nitride or titanium dioxide, the voltage will increase between the metallic and poisoned states.

In theory, the update time for the cathode voltage signal is very fast, but the cathode voltage feedback signal available from the power supply may only be updated every 100 msec or more. Today’s power supplies are controlled with digital electronics, and the cathode voltage output signal may not be updated fast enough for reactive processes. Before deciding on using the cathode voltage signal from your power supply, make sure that the update time for the feedback signal is fast enough for the material you want to deposit.

The advantage of using the cathode voltage signal to control a reactive process is that the signal is readily available. Most power supplies already supply the signal as an output on the back of the supply, and unless you must add a user card to get the signal, the cost of the voltage feedback signal is essentially free.

The main disadvantage of using the cathode voltage as the feedback signal for the reactive sputtering control system is that the signal is not unique. It can and does change for reasons other than a change in the partial pressure of the reactive gas. Outgassing of water vapor, leaks, changes in the argon pressure, variations in the chamber temperature, erosion of the target, other reactive gases, and a disappearing anode all result in changes in the cathode voltage. A disappearing anode has a significant affect on the cathode voltage, rendering the cathode voltage ineffective for controlling the process. As with using an OES feedback signal, the cathode voltage can be very effective in a well maintained and understood system if hidden anodes are used during the reactive sputtering of insulating films.

Lambda Sensor. The lambda sensor measures the conduction of oxygen ions through zirconium dioxide heated to a high temperature, and the oxygen ion current is proportional to the partial pressure of oxygen in the system. This same type of device is used world-wide to measure the oxygen concentration in the exhaust of motor vehicles. In a vacuum system, the instrument must be calibrated, but once this is done - the output of the sensor is the partial pressure of oxygen in the system. The update for the partial pressure is on the order of 100 msec, which is sufficient for many reactive oxide processes. However, some materials are much more reactive with oxygen than others, and the lambda sensor may not work for the more reactive systems.

The cost of a lambda sensor is about the same as an optical sensor that uses a spectrometer. The only disadvantage of the lambda sensor, other than perhaps its update time, is that it only can sense oxygen. A similar type of sensor for nitrogen would be most welcome.

To sum up, today there are four different sensors available for reactive sputtering processes. Each has its advantages and disadvantages. Which one is chosen for a particular process will depend on the funds available and the features needed.

References

For more information, contact William (Bill) Sproul at bsproul@comcast.net.
INTRODUCTION

The world demand for metallized materials in 2003 was estimated by AWA Alexander Watson Associates in their market study published in June 2004, "Metallized Papers & Films: World Sourcebook 2004," as 552,550 tons, equivalent to 21,151 million square meters. This volume does not include vacuum coated products used as stamping foils, products used for the manufacture of metallic pigments, or products used in aerospace or similar high-specification applications.

REGIONAL DEMAND & GROWTH TRENDS

Europe is the largest regional market, with 36% of global volumes consumed. NAFTA uses 26% of global metallized volumes, Asia Pacific 22%, South America 3% and the Rest of the World with 13% (Figure 1).

In general, growth prospects for all metallized materials continue to be encouraging. However, the markets in more developed regions show a slowdown in annual growth rates with pressure on margins and profitability. Less developed regions exhibit strong, continued growth, with investments in technology and capacity to support the growing local demand, and to increasingly compete in export markets.

Growth is stronger in emerging regions such as Asia and Eastern Europe. It is forecast that Asia will overtake the NAFTA territories to become the second largest producer/consumer of metallized products by 2007. Growth is strongest in the Rest of The World, driven by the prospects in India and the development of flexible packaging conversion in the Middle East directed at export markets. Regional volumes and production by materials are shown in Figure 2.

Overall, global demand for metallized materials is forecast to increase at an annualized rate of 7% in the period 2003 to 2007 to an estimated volume of 711,200 tons.

VACUUM COATED MATERIALS

Metallized paper volumes were estimated at 179,100 tons in 2003, equivalent to 32% of the global metallized product market. Metallized film products at 354,700 tons are equivalent to 65% of the global market, the balance being metallized boards and other materials (Figure 3).

Globally, it is estimated that more than 400 companies are actively involved in the metallizing of papers, films, and board materials, and the number of metallizing machines installed worldwide for general trade metallizing is over 650 (excluding stamping foil manufacturers, specialist metallizers, and high-technology and aerospace applications; Figure 4).

The largest market sector for the use of vacuum coated and metallized products is packaging (including cigarettes), which accounts for some 66% of metallized materials in use. The main drivers of growth in the packaging market segment have been barrier performance and aesthetics in the development of metallized films. However, these drivers are now giving way to increased functionality linked to clarity of coating. Recyclability and aesthetics have been and remain the drivers for growth in metallized papers and boards.

In packaging applications, film materials account for 84% of all metallized materials used on an area basis. Cigarette packaging using vacuum metallized papers, boards, and films consumes an estimated 8% of the total volume use of metallized materials. This is a conservative estimate because the volume may be higher if board and paper laminates with...
metallized films were recategorized. This also is the area with greatest growth potential, especially in the Asian market. Labels are an important sector to both metallized films and papers, with metallized label papers accounting for 23% of the total global market for volume use metallized materials (Figure 5).

Figure 5. Principle Market Sectors (Tons). Source: AWA

SOURCING & SUPPLY

The sourcing of vacuum coated and metallized films is becoming more focused globally, as materials-integrated metallizers (film producers) and converter-integrated metallizers (flexible packaging groups) invest further in capacity and technologies through capital investment and acquisition. This has led to several commercial metallizers withdrawing from the toll markets in certain regions.

The paper supply base remains strongly orientated to a strong core of suppliers, and there remain major export opportunities for European paper groups into deep-sea markets. North American paper specifications favor local use.

Expansion of vacuum coating capacities continues, as newer technologies are required to meet demanding specifications on barrier, adhesion, and cost reduction. Very wide width machines (+3 meters) are common for conversion of commodity film products with medium range (1650 mm to 2200 mm) narrow widths for metallizing of specialty grades and papers. There also is a trend to narrower width machines for niche production such as holograms for security use, etc.

Growth prospects are slowing in the mature NAFTA and European markets and are generally in line with GDP growth. Growth in the Indian and mainland Chinese markets are the highest of any region/country, reflecting the high economic growth and continued investment in these areas. Growth in South America is affected by the slower economic climate but is showing a recovery from the lows of earlier years.

In reviewing the metallized materials market as a whole we see the main threats and opportunities as highlighted in the following:

Main Threats and Opportunities for Metallized Materials

- Continuing pressure to reduce costs
- More aggressive buying from customers
- Alternative metallic finishes
- Consolidation across the “Value Chain”
- Smaller-volume orders required more frequently and more quickly
- Need to look at profitability and returns rather than price or volume market share
- Promotion of higher performance metallized films, including clear coatings
- Fuller development and introduction of functional barrier on metallized papers
- Electronic supplier and customer networking
- Quality of offering to equal quality of product
- Continued down gauging of films and papers
- Integration of the metallizing process within other converting processes

For additional information, contact Dr. William Llewellyn at will@awa.com or visit the AWA Web Site at www.awa-bv.com.
Thermal spray processes can be used to deposit some types of sputtering target materials or to build up used target surfaces so they can be remachined. In some cases, because of the latent porosity, such thermal spray deposited target materials are less prone to fracture than are more dense forms of the materials. There are several thermal spray processes, and several of these have been in use since WW II. The thermal spray “guns” (they are never called “torches”) can be operated manually or have a programmable motion.

**Combustion Flame Spraying**

**Wire Flame Spraying**

In about 1912, Schoop developed the first thermal spray system, consisting of a wire or rod fed into a flame created by compressed combustible gases such as acetylene mixed with oxygen. The flame melts the metal, and a stream of compressed air atomizes and propels the molten drops onto a surface. The wire is fed into the gun by serrated rollers. The density of the deposit can be up to 95 vol. %. A schematic of such a gun is shown in Figure 1a. Such a system can be used to deposit low-melting-point materials that don’t oxidize easily, such as zinc or lead. It doesn’t do well on easily oxidized materials such as aluminum, where arc-wire spray is more applicable.

**Powder Flame Spraying**

Powder flame spraying is similar to wire flame spraying except that it uses a powder instead of a wire or rod. The molten particles are accelerated by the flow of the combustion gases. Generally, powder flame spraying gives a more porous deposit (up to 20%) than does wire spraying.

**Ceramic Rod Flame Spraying**

In ceramic rod flame spraying, a ceramic rod is fed down the axis of a high-temperature combustion flame. The surface of the rod is melted, and an air jet ablates the surface and accelerates the molten particles onto a surface. This technique was developed in the 1950s to deposit thermal barrier coatings. An early version was called the “Rokide gun.” Typical ceramics that are flame sprayed are stabilized zirconia, alumina, and spinel.

**Detonation Flame Spraying**

In “D-gun” flame spraying, powder is melted and propelled by an explosion of a mixture of gases ignited by a “spark plug.” The deposit is built up by pulses of material from pulsed explosions. The gun is purged with nitrogen between explosions. Obviously, this can be a tricky business. The advantage is that higher temperatures (4,000°C) and particle velocities (2,400 ft/sec) can be reached. The process is used to deposit hard coatings of materials such as carbides. Mixing powders can generate multiphase materials. Figure 1b shows such a D-gun.

**High-Velocity Oxy/Fuel (HVOF) Spraying Process**

In the early 1980s, the technology of rocket propulsion was extended to the flame spraying of powders. The combustion products of fuel gases such as hydrogen, propane, or propylene with oxygen are expanded through a nozzle where the powders are mixed, heated, and accelerated. Gas velocities can exceed Mach 1 (speed of sound), and particle temperatures can reach 2,000°C. The product can be a fully dense material, but oxidation in transit is still a concern.

**Spraying with Electricity**

**Electric Arc Spraying (Arc Wire Spraying)**

In electric arc spraying, an arc is established between two consumable wire electrodes that are melted in the arc. A stream of compressed gas atomizes the molten material and accelerates the molten particles to the work piece. The wires are fed into the arc, and the power supply is essentially that of an arc welder (75–100 V, 300–500A). By using wires of different materials or of material mixtures, alloy and composite coatings can be deposited. Figure 1c shows such a gun.
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RF Plasma Spraying

In RF plasma spraying, a plasma is generated in a dielectric tube with an RF coil around the outside. Particles are accelerated through the plasma and heated. Particle heating occurs both from heat transfer from the plasma and from electron-ion recombination on the particle surface. For maximum heating, high enthalpy plasmas are used.

Plasma Spraying (Plasma Arc Spraying)

Plasma spray uses a gaseous arc between a tungsten cathode and a water-cooled copper anode. The arc plasma is ejected from the inter-electrode region by the arc gas flow, and a powder of the material to be deposited is injected into the plasma. Particle heating occurs both from heat transfer from the plasma and from electron-ion recombination on the particle surface. Special coated powders can enhance the electron-ion recombination on the particle surface. Figure 1d shows a schematic of an arc plasma spray gun. Plasma spraying can be performed in a vacuum and is called low-pressure plasma spraying (LPPS) or vacuum plasma spraying (VPS). The vacuum system for such a system has bag filters in the exhaust line before the pumps, and a high pumping speed.

In most cases, the configuration is one where the arc is confined to the plasma gun. In some applications, particularly work piece cleaning, an arc can be established between the gun and the work piece. This is called “transferred-arc plasma spraying.”

Postdeposition Processing

Coatings formed by thermal spray processes may be subjected to subsequent processing. These include shot peening or burnishing for ductile materials and heat treatment for stress relief in high modulus materials. In some cases, the thermal spray coating acts as a base for subsequent coatings such as painting.

CONCLUSION

Thermal spray processes have wide applications in industry, particularly when very large areas are involved such as coating ships to prevent galvanic corrosion between dissimilar metals. Thermal spraying is used to deposit hard coatings for wear resistance, porous coatings to retain lubricants and provide a rough surface for painting, buildup scored shafts for re-machining, etc. The process may have many applications in the vacuum coating industry, including renewing sputtering cathodes both inside and outside the deposition system. Thermal plasma spray techniques can also be used to deposit coatings from liquid or vapor precursors.

REFERENCES

Visas, Customs, and Customer Service

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Reference Web Sites:
U.S. DEPT. OF STATE, TRAVEL INFORMATION
For foreign citizens traveling to the United States and American citizens traveling abroad: www.travel.state.gov

U.S. DEPARTMENT OF STATE, VISA INFORMATION
Do you need a visa? Visit this Web Site if you need a visa:
http://travel.state.gov/visa/index.html

Visa applications now require face-to-face interviews at the embassy or consulate in your country, digital fingerprints, and more involved personal data as part of the process. These are new rules and time consuming. The SVC Administrative Office will help you to attend our conference. As soon as you submit your abstract, send your request for the Letter of Invitation immediately to SVC at svcinfo@svc.org.

You will need this Letter of Invitation to accompany your application for a visa, which you must take with you to the interview with the embassy in your country. The whole process can take at least four months depending upon your country of residence. SVC is here to assist you if you start the process early.

SVC has an International Freight Forwarder to assist exhibitors to get their equipment into the United States. Contact the SVC Administrative Office at 505/856-7188 for more information.
CORPORATE SPONSOR PROFILE
Bekaert

Bekaert is a multibillion-dollar technology company that leads the market in advanced metal transformation and advanced material development and coatings. Bekaert has combined sales of €2.7 billion and employs 16,400 people worldwide. The company is headquartered in Belgium and has facilities strategically located throughout the world in 120 countries.

The company is divided into three closely aligned business units: Advanced Wire, Advanced Materials, and Advanced Coatings. These three business units work together to leverage the company’s technical expertise and deliver some of the most effective and important specialized metal products in the world.

The advanced coatings segment includes the application of industrial coatings to various materials by vacuum technologies or thermal spraying. Bekaert supplies special equipment, predominately for customers in the glass industry, for large area coating, and produces window film for applications in automotive and architectural sectors.

Industrial customers who require large area glass coating or specialty film applications for architectural and automotive glass, display glass and photovoltaic glass, can capitalize on Bekaert’s innovative technology, industry-leading research and development and world-class customer support.

Bekaert combines expertise and market leadership in rotatable magnetron technology and rotatable sputter targets to deliver the highest-quality large area coating solutions. Bekaert’s technology allows customers to switch from planar to rotatable targets and offers a lower cost of ownership through longer production runs, faster coating deposition, and a more complete use of coating material. Bekaert was the first to bring rotatable targets to the market and has developed the necessary sputter equipment to effectively use these targets on glass coating lines all over the world. Bekaert addresses the needs of global customers through strategically located manufacturing, service, and sales offices in Deinze, Belgium; Spring Green, Wisconsin; and throughout Asia, including Japan, Korea, and China. Many of Bekaert’s facilities are ISO 9001/2000 certified.

Bekaert is also a leading global supplier of solar control and safety window films for automotive, architectural, and commercial applications and is the foremost provider of highly sophisticated vacuum sputtered, wet coated, and laminated flexible film products for various industrial applications. With more than 25 years in the research, development, and manufacturing of high-performance coatings onto flexible polymeric films, Bekaert continues to invest in core competencies of vacuum web sputtering and precision web coating and laminating to meet the changing market demand for high-performance specialty films. Bekaert distributes its window film products to independent dealers via 20 company-owned offices to over 60 countries around the globe.

Additional information is available at www.bekaert.com/bac and www.bekaertfilms.com.
On-line courses offer the opportunity to attend classes at your own convenience, at any time, and in any place.

In an on-line course the instructor and course registrants are interconnected through a computer network. Using the Internet, you can at any time receive instruction, compose and submit assignments, ask questions of the instructor and other registrants, discuss issues, and actively participate in the class from your home, your office, or the nearest campus computer laboratory.

The opportunity to participate in this Learning Program is co-sponsored by the University of Delaware and the Society of Vacuum Coaters, through the distance learning system—UD Online. This new approach to teaching and learning is student-centered. It eliminates the constraints of time and location that other education programs normally place on course registrants. Registrants who complete the course receive Continuing Education Units (CEUs). The program emphasizes innovative instruction and learning. The instructor and course registrants can leverage the wealth of resources available through the Internet to support this instruction.

Course Description:
This Fundamentals of Vapor Deposition course will introduce students to essential concepts involved in using vapor deposition techniques to create thin film materials. Students will be exposed to core concepts of the most common types of vapor deposition technologies. In addition, topics in nucleation and growth of films, kinetics of vapor deposition of films, and failure mechanisms of films will be presented in order to develop an understanding of the connection between vapor deposition parameters and thin film properties. The information presented in the course will be useful for professionals who are new to the field of vapor deposition as well as for practitioners already in the field of vapor deposition who want to learn more about vapor deposition technology related to their field of expertise. No prior formal training in vapor deposition technologies is required for students to benefit from the course.

Course Content:
- Thermal evaporation
- Nucleation and growth of thin films
- Failure mechanisms of thin films
- Sputtering
- Chemical vapor deposition
- Kinetics of vapor deposition
- Molecular beam epitaxy

The material presented in the course is equivalent to the amount of information covered in one, eight-hour duration “live” course. Registered students will receive a CD that contains the course content. Students are permitted to retain the CD following the course. Students can complete the course at their own pace over a designated two-week period. During this time, students will be able to contact the instructor privately via E-mail with questions. Students also will be able to participate in group discussions of questions on line. Each unit (listed above) will have a discussion page on which students can post questions specific to the content in that unit. The instructor will answer the posted questions daily, and students are welcome to participate in the discussion of topics raised on the discussion pages by other students.

In order to complete the course, the instructor will ask each student to provide a short answer essay (500 words or less) to a question based on practical applications involving vapor deposition. The student may pick one question to answer from a list of several questions.

Course Materials: CD-ROM titled, “Interfacial Systems Engineering Vapor Deposition,” published by WESEECO™

Fees: Early Registration—$385; Late Registration—$415. Shipping of CD outside the U.S. and Canada is an additional $40.

Class Size: Limited to 20 registrants

Instructor: S. Ismat Shah, University of Delaware
Professor Shah received his Ph.D. from the University of Illinois at Urbana-Champaign. He worked for Dupont Company for 12 years before joining the University of Delaware. He has a joint appointment in the departments of Materials Science and Engineering and Physics and Astronomy. He also works as the Manager of the Nanostructured Materials Program at the Fraunhofer Center, Delaware. Professor Shah has been involved with thin films and nano-structured materials for more than 20 years. He has over 80 publications and 6 patents in the area of thin films and nanostructures. His expertise includes PVD and CVD processes, photocatalysis, electronic materials, magnetic materials, etc.
The 8th International Symposium on Sputtering & Plasma Processes, ISSP 2005, was held from June 8–10, in Kanazawa Kokusai Hotel, Kanazawa, Japan. Kanazawa is the biggest city in the Hokuriku region, surrounded by Hakusan and Noto Peninsula National Parks.

The International Symposium on Sputtering & Plasma Processes was established in 1991 and is held every other year. The symposium is sponsored by the Japan Vacuum Society. Ten related societies, mostly from Japan, are involved in the symposium as assisting societies.

Dr. Yukio Yoshino from MURATA MTG. Co. Ltd. was the Symposium Chair of the ISSP 2005 and Prof. Eiji Kusano from Kanazawa Institute of Technology acted as a Vice Chair. Many members of the program committee are researchers from or connected to industry. There is always a strong participation from industry at the ISSP, together with attendees and presentations from research institutes and universities. Besides invited and contributed presentations and posters, there were manufacturers’ presentations given in the technical program. All authors, including invited speakers and manufacturers, made their presentations also at the evening poster sessions. This arrangement enabled attendees of the symposium to discuss presented results with all authors in detail. During three days, around 120 presentations were given to more than 250 participants.

The symposium focused on recent topics in the field of sputtering and plasma processes. The program was organized into the following sessions:

- Fundamentals of Sputtering and Plasma Processes
- Sputtering Processes
- Plasma Processes
- Thin Films
- Micro and Nanotechnologies
- Applications.

The Industrial Exhibition

The ISSP Panel Exhibit featured process equipment, systems, related materials and components, and services for sputtering and plasma processes. The exhibition was open throughout the whole conference concurrent with the poster sessions.

SVC acted as an assisting society to ISSP 2005. Hana Baránková represented SVC at the ISSP. The SVC had a panel and desk available with materials for distribution at the ISSP Panel Exhibit. Hana Baránková also gave an SVC-sponsored presentation on hollow cathode and hybrid plasma processing and introduced the SVC in conjunction with the invited presentation. The SVC 2006 TechCon to be held in Washington, DC was highlighted. The Call for Papers (SVC TechCon 2006) ad was also printed in the ISSP Proceedings.

SVC and ISSP will keep in contact and strengthen the relationship between both organizations with an eye toward further collaboration on symposiums organized by SVC and ISSP.

Hana Baránková, Uppsala University, (hana.barankova@angstrom.uu.se), is the SVC Director of Technical Advisory Committees.
AVEM Tutorial on
THE FUTURE OF VACUUM SYSTEMS:
STRATEGIC ADAPTABLE INTEGRATED VACUUM

Monday, Oct 31, 2005 7:45-10:00 a.m. Sheraton Boston Hotel, Boston, MA
Presented by Dr Richard J.Wilk,
Administrative Officer for the Department of Chemistry, Massachusetts Institute of Technology

The necessity of research organizations to readily adapt to emerging technologies and constantly changing global market conditions is driving the design and construction of new technical facilities. The vacuum requirements of research and analytical laboratories continue to evolve. Present and future trends in the planning of research and analytical communities will be discussed. The seamless integration of vacuum systems is also emerging as a critical design factor for laboratories of all disciplines, especially in the pharmaceutical, biotechnology and medical device industries. Multi-disciplinary areas such as nanotechnology will introduce new requirements for instrumental and laboratory applications. The burgeoning homeland security industry is expected to generate special challenges for both laboratory and field deployable systems.

Join the AVEM networking continental breakfast at 7:45 a.m. prior to the opening of the AVS 52nd International Symposium. This breakfast precedes the AVEM Tutorial at 8:30 a.m., and the AVEM Annual Business meeting at 9:30 a.m.

DO NOT MISS this enlightening and timely presentation. There is no charge to attend the events, but registration on or before October 27 is required.

For more information, go to www.avem.org, E-mail aveminfo@avem.org or phone 505/856-6924.

The Association of Vacuum Equipment Manufacturers International (known as AVEM) will hold a Spring Seminar in Santa Clara, CA, on the morning of February 22, 2006. The seminar titled, “The Latest Market Trends, Vacuum Techniques and Technologies,” will feature keynote speakers from SEMI and the Lawrence Livermore National Laboratory. All speakers will address current topics of interest to those working in vacuum-related technology fields. Before the seminar, network with experts at the buffet breakfast at 7:45 a.m., an integral part of this program. After the seminar, visit the Northern California Chapter AVS Equipment Exhibit that opens on the afternoon of February 22. Do not miss this opportunity to gain knowledge on several different equipment market sectors. For more information contact AVEM at aveminfo@avem.org.

The AVS 52nd International Symposium will be held October 30–November 4, 2005, at the Hynes Convention Center in Boston, MA. Highlights include an extensive collection of technical symposia, workshops, and topical conferences. Technical Symposia include: Advanced Surface Engineering; Applied Surface Science; Biomaterial Interfaces; Electronic Materials and Processing; Magnetic Interfaces and Nanostructures; MEMS and NEMS; Manufacturing Science and Technology; Nanometer-Scale Science and Technology; Plasma Science and Technology; Surface continued on page 50

Election of SVC Officers and Directors

The Society of Vacuum Coaters is pleased to announce the election of H. Angus Macleod, Thin Film Center, Inc. to the position of SVC Vice President and President-elect. He will assume this office on Sunday April 23, 2006, at the SVC Annual Business Meeting.

SVC is also pleased to announce that David A. Glocker, Isoflux Incorporated, was re-elected for a second two-year term as the SVC Secretary. At the Annual Business Meeting Peter Martin, Battelle Pacific Northwest Laboratory, will assume the position of SVC President, and the current President, Clark Bright, 3M Company, will become the SVC Past President. Michael Andreasen, VACUUM COATING Technologies, Inc. will continue in his position as SVC Treasurer.

SVC members have been nominated to serve three-year terms.

• Pamela Diesing, Sage Industrial Sales, Inc.
• Ludvik Martinu, École Polytechnique, Canada
• William D. Sproul, Reactive Sputtering Consulting, LLC
• Frank Zimone, Denton Vacuum, LLC

Please return your ballots to the SVC Administrative Office on or before November 17, 2005.

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For an up-to-date list of course descriptions and instructor biographical sketches, please visit the SVC Web Site at www.svc.org and explore the “Education Programs” button on the main page.

For technical questions regarding the course content, contact the SVC Administrative Office at svcinfo@svc.org, or Fax 505/856-6716.

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SVC Course Roster
V-201 High Vacuum System Operation
V-202 Vacuum System Gas Analysis
V-203 Vacuum Materials and Large System Performance
V-206 Practical Helium Leak Detection Workshop
V-207 Practical Aspects of Vacuum Technology: Operation and Maintenance of Production Vacuum Systems
V-301 Care and Feeding of Mechanical Pumping Systems
V-304 Cryogenic High Vacuum Pumps
C-101 Primer on Thin Films and Vacuum Technology
C-102 Introduction to Evaporation and Sputtering
C-103 An Introduction to Physical Vapor Deposition (PVD) Processes
C-203 Sputter Deposition
C-207 Evaporation as a Deposition Process
C-208 Sputter Deposition in Manufacturing
C-209 Material Science Aspects of Plasma Processing
C-210 Introduction to Plasma Processing Technology
C-212 Troubleshooting for Thin Film Deposition Processes
C-213 Introduction to Smart Materials
C-214 Pulsed Plasma Processing
C-301 Optical Coating Design and Monitoring
C-302 Preparation and Properties of Optical Thin Film Materials
C-303 Design and Manufacture of Optical Coatings Using Computer Methods
C-306 Nonconventional Plasma Sources and Methods in Processing Technology
C-307 Cathodic Arc Plasma Deposition
C-308 Tribological Coatings
C-310 Plasma Immersion Techniques for Surface Engineering
C-311 Thin Film Growth and Microstructure Evolution
C-312 Process Control for Applications in Large Area Sputtering
C-314 Plasma Web Treatment
M-101 Basic Principles of Color Measurement

Course Classification System

The course codes are intended to provide the prospective attendee with some guidance as to whether the emphasis in the course is primarily on vacuum technology (V code), or vacuum deposition coating processes and technology (C code), or other miscellaneous topics (M code). The course number is intended to indicate the level of course specialization—the lower numbers refer to courses that are basic or introductory in nature, and the higher numbers refer to courses that offer a more specialized treatment of a specific topic.
CeramTec North America is pleased to announce that Tom Finnerty has been named Vacuum Solutions Group’s new representative for the mid-Atlantic territory. Tom Finnerty will manage all sales activities for DE, MD, DC, VA, and eastern NC from his office location in the DC/Baltimore area, which includes being the primary sales and technical service contact for all of CeramTec’s Hermetic Product customers in this region. Tom Finnerty brings to VSG and CeramTec more than twelve years sales and management experience in the vacuum industry. He can be reached at 301/829-1304. “Vacuum Solutions Group, Inc. and most of our suppliers have identified the mid-Atlantic area as a strategic opportunity to grow sales of all products. We strongly believe that Tom Finnerty has the ideal market and product knowledge, as well as excellent sales and administrative skills to aggressively grow current account sales and capture new customer opportunities in this region,” commented Perry Henderson of Vacuum Solutions Group.

CeramTec is entering its second century of ceramic manufacturing and has additional manufacturing facilities in Asia and Europe. The company’s website is www2.ceramtec.com

Applied Films Corporation has assigned Matt Denninger to be the Director, Sales & Marketing Americas, effective September 1. Matt is responsible for sales and service to the web, solar cell, architectural glass and display equipment markets throughout the Americas. Matt returned to the US with his family after having lived and worked in Asia for four-and-a-half years, first as Sales Director of Applied Films Asia Pacific Limited in Hong Kong and then as President of Applied Films Japan Co., Ltd. in Tokyo.


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Science; Technology for Sustainability; Thin Films; and Vacuum Technology. Topical Conferences and Special Sessions will take place on the following subjects: DNA; Renewable and Alternate Energy; Science of Semiconductor White Light; Biomaterials Plenary Session; and Exhibitor Workshop. In addition, a plenary lecture will be presented by R. Stanley Williams, HP Senior Fellow of Hewlett-Packard Laboratories on “The Crossbar Architecture for Nanoelectronics.” For more information on the International Symposium, access the AVS Website at www.avs.org, or contact the AVS at 212-248-0200, fax 212-248-0245, E-mail avsnyc@avs.org. The Distance Learning Self-Paced Course on “Fundamentals of Vacuum Deposition” (which is sponsored by SVC in collaboration with the University of Delaware) will be held November 28–December 8, 2005. See page 45 of this Bulletin for full details.

The Society of Vacuum Coaters Foundation, Inc. is accepting applications to the Scholarship Fund. This fund was established to assist selected individuals to further their education in a program of study important to vacuum coating technology. The deadline for receipt of applications is January 31, 2006. For information visit the SVC Web Site at www.svc.org under the SVC Foundation/Scholarship Program button. All inquiries concerning the scholarship program should be directed to the Foundation by E-mail to svcfoundation@svc.org. The SVC Foundation is seeking donations from corporations and individuals who wish to support this program. All donations are tax deductible. Donations can be mailed to the Society of Vacuum Coaters Foundation, Inc., 71 Pinon Hill Place, NE, Albuquerque, NM 87122-1914, USA.

The Conference on Lasers and Electro-Optics (CLEO 06) will be held at the Long Beach Convention Center, Long Beach, CA, on May 21–26, 2006. For details visit www.cleoconference.org.

The advertising deadline for the Winter Bulletin is Dec. 1, 2005. Call 505/856-7188 or E-mail svcinfo@svc.org for information on advertising in the Bulletin. Or visit our Web Site at www.svc.org to download a PDF of the Media Kit.
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