

# **72<sup>nd</sup> IUVSTA Workshop**

on

## **Plasma-assisted vapour deposition of oxide-based thin films and coatings**

**6 – 11 April 2014, Schloss Seggau, Austria**

**Sponsored by the IUVSTA Surface Engineering Division**

### **1. Scientific Report**

The 72<sup>th</sup> IUVSTA Workshop was held in the wine region of southern Styria in Austria from 6 – 11 April 2014. It attracted 55 attendees from 18 countries (see the attached list of participants). The workshop was organized by the IUVSTA Surface Engineering Division, with support from the Thin Film and Plasma Science & Technique Divisions. The workshop venue was Schloss Seggau, the seat of the Styrian Bishopric until 1786 and the summer residence of its Bishops until the mid-20th century, located on a hill near the tiny village Leibnitz, about 35 km from Graz. This secluded location offering meeting rooms, accommodation and meals for the workshop attendees guaranteed an event, in which intensive interaction took place.

The workshop addressed all issues encountered in the synthesis and characterisation of oxide-based thin films and coatings used in various application areas such as optical and hard coatings, transparent conductive oxides, thermochromic and electrochromic thin films, decorative coatings, and photocatalytic films. Its scope was to bring together scientists and researchers working in these different areas, to stimulate discussions and to create synergies. 20 leading scientists from Austria, Belgium, Canada, Czech Republic, Germany, Liechtenstein, Singapore, Slovenia, South Korea, Switzerland, U.K., and USA accepted invitations to present their recent achievements in this rapidly growing field (see attached list of invited speakers and titles of their presentations). Typical methods employed for synthesising these materials that were discussed during the workshop include sputtering techniques, e.g. magnetron sputtering, pulsed and rf sputtering as well as high power impulse magnetron sputtering (HiPIMS) but also cathodic arc evaporation and plasma-enhanced chemical vapour deposition. Additional 21 attendees presented their work in talks and poster presentations. Ample time was planned and used for discussions. The duration of the workshop was four and a half days.

The scientific programme of the workshop was developed by the members of the Scientific Committee, Andre Anders (Lawrence Berkeley National Laboratory, Berkeley, CA, USA), Robert Franz (Montanuniversität Leoben, Austria), Christian Mitterer (Montanuniversität Leoben, Austria) und Jochen Schneider (RWTH Aachen, Germany). Local organization was done by Robert Franz (website, programme and abstract book, budgeting, contracts for accommodation, meals and refreshment), Angelika Tremmel (registration and accounting), Tanja Jörg and Julia Pachlhofer (on-site registration, audio-visual facilities). Additional support was provided by the Austrian Vacuum Society, the Central European Initiative and the Montanuniversität Leoben.

The scientific program of the workshop can also be found in the attached pages. In each session, sufficient time was provided for intense scientific discussions between the speaker and the attendees. The individual sessions were moderated by selected experts on the particular topics.

Also included was an overview on IUVSTA and the Surface Engineering Division, which was presented by Christian Mitterer.

The workshop was complemented by a Welcome Reception on Sunday evening, a visit to the historic Seggau Castle and an evening wine tasting on Wednesday in the 300 years old wine cellar of the castle.

## 2. Financial Report

It is certified that the IUVSTA funds for the 72<sup>nd</sup> IUVSTA Workshop on “Plasma-assisted vapour deposition of oxide-based thin films and coatings” of 6000 Euros were completely used to cover the costs for workshop registration, accommodation and meals for the invited speakers, as specified in detail in the list below. The overall workshop budget was break-even.

Uroš Cvelbar (Jozef Stefan Institute, Slovenia)	375
Diederik Depla (Ghent University, Belgium)	375
Gregory J. Exarhos (Pacific Northwest National Laboratory, USA)	375
Jeongeon Han (Sungkyunkwan University, Korea)	375
Peter Kelly (Manchester Metropolitan University, UK)	375
Christoph Leyens (Technische Universität Dresden, Germany)	375
Ludvik Martinu (Polytechnique Montréal, Canada)	375
Peter Mascher (McMaster University, Canada)	375
Jörg Patscheider (Empa, Switzerland)	375
Ganpati Ramanath (Rensselaer Polytechnic Institute, USA)	375
Jürgen Ramm (Oerlikon Balzers, Liechtenstein)	375
Christina Scheu (Ludwig-Maximilians-University Munich, Germany)	375
Rony Snyders (Université de Mons, Belgium)	375
Bernd Szyszka (Technische Universität Berlin, Germany)	375
Beng Kang Tay (Nanyang Technological University, Singapore)	375
Jaroslav Vlcek (University of West Bohemia, Czech Republic)	375
<b>Total support:</b>	<b>6000 Euro</b>

## Invited Speakers (in alphabetical order)

**André Anders** (Lawrence Berkeley National Laboratory, USA): Oxide films and oxide nanoparticles via physical vapor deposition

**Uroš Cvelbar** (Jozef Stefan Institute, Slovenia): Deterministic growth of metal oxide nanowires in oxygen plasma

**Diederik Depla** (Ghent University, Belgium): Fundamentals of sputtering oxide thin films

**Gregory J. Exarhos** (Pacific Northwest National Laboratory, USA): Harnessing defects in TCO films for properties optimization

**Robert Franz** (Montanuniversität Leoben, Austria): Effects in oxygen containing plasmas used in physical vapour deposition

**Jeongeon Han** (Sungkyunkwan University, Korea): Functional oxide synthesis at low temperature by control of radicals in PECVD

**Peter Kelly** (Manchester Metropolitan University, U.K.): Photocatalytic titania coatings by magnetron sputtering techniques

**Christoph Leyens** (Technische Universität Dresden, Germany): Oxide conversion for improved coating performance – A self-healing approach

**Ludvik Martinu** (Polytechnique Montréal, Canada): Plasma deposited structurally tailored oxide films for passive and active optical filters and energy control applications

**Peter Mascher** (McMaster University, Canada): Visible light emission from silicon-based thin films fabricated by PECVD

**Christian Mitterer** (Montanuniversität Leoben, Austria): Growth, microstructure and properties of arc evaporated (Al,Cr)<sub>2</sub>O<sub>3</sub> hard coatings

**Jörg Patscheider** (Empa, Switzerland): Designing the thermal conductivity of hard oxynitride coatings

**Ganpati Ramanath** (Rensselaer Polytechnic Institute, USA): Molecularly-tailored inorganic nanomaterials and interfaces

**Jürgen Ramm** (Oerlikon Balzers, Liechtenstein): Cathodic arc evaporation of oxide coatings for high temperature applications

**Christina Scheu** (Ludwig-Maximilians-University Munich, Germany): Advanced structural characterization of oxides

**Jochen Schneider** (RWTH Aachen, Germany): Growth of alumina thin films by PVD: Effect of intentional and unintentional alloying elements on phase formation and film properties

**Rony Snyders** (Université de Mons, Belgium): What controls the phase formation of reactively sputtered metal oxide thin films?

**Bernd Szyszka** (Technische Universität Berlin, Germany): Recent developments in the field of transparent conductive oxide films and emerging applications for automotive and architectural glazing, oxide electronics and photovoltaics

**Beng Kang Tay** (Nanyang Technological University, Singapore): The evolution and impacts of filtered cathodic vacuum arc technology

**Jaroslav Vlcek** (University of West Bohemia, Czech Republic): High-rate reactive high-power impulse magnetron sputtering of densified dielectric oxide films

## Programme

	Monday	Tuesday	Wednesday	Thursday	Friday
8:30 – 8:50	Welcome note	<b>André Anders</b>	<b>Christina Scheu</b>	<b>Gregory J. Exarhos</b>	<b>Christian Mitterer</b>
8:50 – 9:10	<b>Diederik Depla</b>				
9:10 – 9:30		<b>Jaroslav Vlcek</b>	<b>Ganpati Ramanath</b>	<b>Ludvik Martinu</b>	<b>Bernd Szyszka</b>
9:30 – 9:50					
9:50 – 10:10	coffee break	coffee break	coffee break	coffee break	coffee break
10:10 – 10:30					
10:30 – 10:50	<b>Beng Kang Tay</b>	<b>Uroš Cvelbar</b>	<b>Peter Mascher</b>	<b>Jörg Patscheider</b>	<b>Christoph Leyens</b>
10:50 – 11:10		Stephanos Konstantinidis	Henry Morgner	Michael Stüber	Closing remarks
11:10 – 11:30					
11:30 – 11:50	Bert Scheffel	Holger Gerdes	Harald Köstenbauer	Jörn Kohlscheen	
	lunch	lunch	lunch	lunch	lunch
13:30 – 13:50	<b>Robert Franz</b>	<b>Rony Snyders</b>	<b>Jeon G. Han</b>	<b>Jürgen Ramm</b>	
13:50 – 14:10					
14:10 – 14:30	Jiří Čapek	Petr Zeman	Cédric Guyon	Ludvig Landälv	
14:30 – 14:50	Siegfried Krassnitzer	Christian M. Koller	Carles Corbella	Timo Jäger	
14:50 – 15:10	Poster Session (+coffee break)	coffee break	coffee break	coffee break	
15:10 – 15:30					
15:30 – 15:50		<b>Jochen Schneider</b>	Individual discussions	<b>Excursion (castle visit)</b>	
15:50 – 16:10					
16:10 – 16:30		Rostislav Daniel			
16:30 – 16:50					
18:00 – 19:00	dinner	dinner	dinner	dinner	
19:30 – 20:30			<b>Wine tasting</b>		

Monday, 7 April 2014

Time	Authors	Title
8:30 – 8:50	Robert Franz, Christian Mitterer	Welcome note
8:50 – 9:10	<b>Diederik Depla</b>	Fundamentals of sputtering oxide thin films
9:10 – 9:30		
9:30 – 9:50	<b>Jaroslav Vlcek, Jiri Rezek</b>	High-rate reactive high-power impulse magnetron sputtering of densified dielectric oxide films
9:50 – 10:10		
coffee break		
10:50 – 11:10	<b>Beng Kang Tay</b>	The evolution and impacts of filtered cathodic vacuum arc technology
11:10 – 11:30		
11:30 – 11:50	Bert Scheffel, Christoph Metzner, Thomas Modes	Spotless arc activated high-rate deposition of titanium dioxide coatings onto metal strip
lunch		
13:30 – 13:50	<b>Robert Franz</b>	Effects in oxygen containing plasmas used in physical vapour deposition
13:50 – 14:10		
14:10 – 14:30	Stanislav Kadlec, Jiří Čapek, Jaroslav Kousal, Jiří Vyskočil	On the balance of powers delivered to magnetrons and of corresponding deposition rates in reactive bipolar pulsed HIPIMS of aluminium and titanium oxides
14:30 – 14:50	Siegfried Krassnitzer, Denis Kurapov, Helmut Rudigier	Progress in hysteresis free aluminum oxide deposition process with S3p™ technology
14:50 – 16:30	<b>Poster Session (+ coffee break)</b>	

Tuesday, 8 April 2014

Time	Authors	Title
8:30 – 8:50	<b>André Anders</b>	Oxide films and oxide nanoparticles via physical vapor deposition
8:50 – 9:10		
9:10 – 9:30	<b>Ganpati Ramanath</b>	Molecularly-tailored inorganic nanomaterials and interfaces
9:30 – 9:50		
coffee break		

10:30 – 10:50	<b>Uroš Cvelbar</b>	Deterministic growth of metal oxide nanowires in oxygen plasma
10:50 – 11:10		
11:10 – 11:30	S. Konstantinidis, P.-A. Cormier, A.-L. Thomann, A. Balhamri, R. Dussart, N. Semmar, T. Lecas, R. Snyders	Energy flux measurements during magnetron sputter deposition of metal oxide thin films
11:30 – 11:50	Holger Gerdes, Ralf Bandorf	Different HIPIMS techniques for reactive deposition of alumina
lunch		
13:30 – 13:50	<b>Rony Snyders, Pierre-Antoine Cormier, Anne-Lise Thomann, Moshin Raza, Stephanos Konstantinidis</b>	What controls of the phase formation of reactively sputtered metal oxide thin films?
13:50 – 14:10		
14:10 – 14:30	Petr Zeman, S. Zuzjakova, S. Kos, R. Cerstvy, J. Musil	Transformation phenomena in metastable alumina coatings
14:30 – 14:50	Christian M. Koller, D. Holec, J. Ramm, S. Kolozsvari, J. Paulitsch, P. H. Mayrhofer	Alloying trends of refractory metals on the phase stability of $(Al_{1-x}Cr_x)_2O_3$ coatings
coffee break		
15:30 – 15:50	<b>Jochen Schneider</b>	Growth of alumina thin films by PVD: Effect of intentional and unintentional alloying elements on phase formation and film properties
15:50 – 16:10		
16:10 – 16:30	Rostislav Daniel, Jozef Keckes, Christian Mitterer	Microstructural and stress design of thin films: The journey from nitrides to oxides, from nanocrystalline to amorphous materials

### Wednesday, 9 April 2014

Time	Authors	Title
8:30 – 8:50	<b>Christina Scheu</b>	Advanced structural characterization of oxides
8:50 – 9:10		
9:10 – 9:30	<b>Ludvik Martinu</b>	Plasma deposited structurally tailored oxide films for passive and active optical filters and energy control applications
9:30 – 9:50		
coffee break		
10:30 – 10:50	<b>Peter Mascher</b>	Visible light emission from silicon-based thin films fabricated by PECVD
10:50 – 11:10		
11:10 – 11:30	Henry Morgner, Christoph Metzner, Olaf Zywitzki	High rate deposition of SiO <sub>x</sub> -layers using hollow cathode arc discharge plasma sources
11:30 – 11:50	Harald Köstenbauer, D. Lorenz, J. Winkler, B. Tseng, G. Jakopic, W. Theiss	Molybdenum oxides and oxynitrides for low-reflectance thin films in touch applications

	lunch	
13:30 – 13:50	<b>Jeon G. Han, Jun S. Lee, Jay B. Kim</b>	Functional oxide synthesis at low temperature by control of radicals in PECVD
13:50 – 14:10		
14:10 – 14:30	Cédric Guyon, Anais Terbèche, Deng Yue, Philippe Barboux, Michael Tatoulian	Elaboration of thin films for ionic sensors by a PECVD process
14:30 – 14:50	<b>Carles Corbella</b>	Upscaling plasma deposition: the influence of technological parameters
	coffee break	
15:30 – 16:50	Individual discussions	

### Thursday, 10 April 2014

Time	Authors	Title
8:30 – 8:50	<b>Gregory J. Exarhos</b>	Harnessing defects in TCO films for properties optimization
8:50 – 9:10		
9:10 – 9:30	<b>Bernd Szyszka, Ruslan Muydinov, Andreas Pflug, Bernd Rech, Florian Ruske, Harald Scherg-Kurmes, Rutger Schlatmann, Volker Sittinger, Bernd Stannowski, Stephan Ulrich</b>	Recent developments in the field of transparent conductive oxide films and emerging applications for automotive and architectural glazing, oxide electronics and photovoltaics
9:30 – 9:50		
	coffee break	
10:30 – 10:50	<b>Jörg Patscheider, P.H. Michael Böttger, Valery Shklover, Matthias Sobiech</b>	Designing the thermal conductivity of hard oxynitride coatings
10:50 – 11:10		
11:10 – 11:30	Michael Stüber, Stefanie Spitz, Harald Leiste, Sven Ulrich	Microstructure and properties of as-deposited and vacuum annealed r.f. magnetron sputtered Cr-Zr-O thin films
11:30 – 11:50	<b>Jörn Kohlscheen</b>	Study of PVD oxide coatings in milling
	lunch	
13:30 – 13:50	<b>Xavier Maeder, Max Döbeli, Alex Dommann, Antonia Neels, Jürgen Ramm, Helmut Rudigier, Beno Widrig</b>	Cathodic arc evaporation of oxide coatings for high temperature applications
13:50 – 14:10		
14:10 – 14:30	Ludvig Landälv, Emmanuelle Göthelid, Mats Ahlgren, Lars Hultman, Björn Alling, Per Eklund	Influence of Si doping on process stability and coating properties during arc deposition of (Al, Cr)2O3
14:30 – 14:50	Timo Jäger, Yaroslav E. Romanyuk, Ayodhya N. Tiwari, André Anders	Controlling ion fluxes during reactive sputter-deposition of SnO <sub>2</sub> :F
	coffee break	
15:30	<b>Excursion (castle visit)</b>	

## Friday, 11 April 2014

Time	Authors	Title
8:30 – 8:50	<b>Christian Mitterer</b>	Growth, microstructure and properties of arc evaporated (Al,Cr) <sub>2</sub> O <sub>3</sub> hard coatings
8:50 – 9:10		
9:10 – 9:30	<b>Peter Kelly, Glen West, Marina Ratova, Joanna Verran</b>	Photocatalytic titania coatings by magnetron sputtering techniques
9:30 – 9:50		
coffee break		
10:30 – 10:50	<b>Christoph Leyens</b>	Oxide conversion for improved coating performance
10:50 – 11:10		
11:10 – 11:30	André Anders, Jochen Schneider	Closing remarks
lunch		

## Posters

Authors	Title
Yin-Yu Chang, Chung-Yin Tu, Heng-Li Huang	Effect of silver doping on the cytocompatibility and antibacterial properties of tantalum oxide and zirconia coatings
Mohsin Raza, G. Geumez, T. Van Regemorter, R. Snyder, S. Konstantinidis	Understanding the phase formation in zirconium oxide thin films
Jonathan Dervaux, P.-A. Cormier, S. Konstantinidis, R. Snyders	Synthesis of porous crystalline TiO <sub>2</sub> thin films by glancing angle reactive magnetron sputtering
Rémy Francq, P.-A. Cormier, R. Snyders	Deposition of ZnO-Ag composite by reactive magnetron co-sputtering: structural and morphological characterizations
O. Zabeida, R. Vernhes, T. Poirié, S. Chiarotto, K. Scherer, T. Schmitt, V. Marushka, L. Martinu, Jolanta E. Klemberg-Sapieha	Hybrid organic-inorganic optical films deposited by ion beam assisted CVD



## List of Attendees

Attendee	Organisation
Jaroslav Vlcek	University of West Bohemia, Czech Republic
Diederik Depla	Ghent University, Belgium
Christina Scheu	Max-Planck-Institut für Eisenforschung, Germany
Gregory J. Exarhos	Pacific Northwest National Laboratory, USA
Ganpati Ramanath	Rensselaer Polytechnic Institute, USA
Beng Kang Tay	Nanyang Technological University, Singapore
Rony Snyders	Université de Mons, Belgium
Jörg Patscheider	Empa, Switzerland
Peter Mascher	McMaster University, Canada
Ludvik Martinu	Polytechnique Montreal, Canada
Jeon G. Han	Sungkyunkwan University, Korea
Jürgen Ramm	Oerlikon Balzers Coating AG, Liechtenstein
Peter Kelly	Manchester Metropolitan University, UK
Christoph Leyens	Technische Universität Dresden, Germany
Bernd Szyszka	Technische Universität Berlin, Germany
Uroš Cvelbar	Jozef Stefan Institute, Slovenia
Robert Franz	Montanuniversität Leoben, Austria
Christian Mitterer	Montanuniversität Leoben, Austria
André Anders	Lawrence Berkeley National Laboratory, USA
Jochen Schneider	RWTH Aachen University, Germany
Jörn Kohlscheen	Kennametal GmbH, Germany
Yin-Yu Chang	National Formosa University, Taiwan
Siegfried Krassnitzer	Oerlikon Balzers Coating AG, Liechtenstein
Ludvig Landälv	Linköping University, Sweden
Mohsin Raza	Université de Mons, Belgium
Jonathan Dervaux	Université de Mons, Belgium
Rémy Francq	Materia Nova Research Center, Belgium
Henry Morgner	Fraunhofer-Institut FEP, Germany
Christian M. Koller	Vienna University of Technology, Austria
Michael Stüber	Karlsruhe Institute of Technology (KIT), Germany
Stephanos Konstantinidis	Université de Mons, Belgium
Bert Scheffel	Fraunhofer-Institut FEP, Germany
Petr Zeman	University of West Bohemia, Czech Republic
Cédric Guyon	Chimie ParisTech, France
Jiří Čapek	University of West Bohemia, Czech Republic
Harald Köstenbauer	Plansee SE, Austria

J.E. Klemberg-Sapieha	Polytechnique Montreal, Canada
Timo Jäger	Empa, Switzerland
Rostislav Daniel	Montanuniversität Leoben, Austria
Matjaz Panjan	Jožef Stefan Institute, Slovenia
Holger Gerdes	Fraunhofer Institute IST, Germany
Carles Corbella	Ruhr-University Bochum, Germany
Katrin Zorn	Miba Coating Group, Austria
Julia Pachlhofer	Montanuniversität Leoben, Austria
Tanja Jörg	Montanuniversität Leoben, Austria
Peter Polcik	PLANSEE Composite Materials GmbH, Germany
Chung-Yin Tu	National Formosa University, Taiwan
Marc Horstink	IHI Hauzer Techno Coating B.V., Netherlands
Ulrich Albers	Walter AG Tübingen, Germany
Chenyi Li	Beihang University, China
Mirjam Arndt	Oerlikon Balzers Coating AG, Liechtenstein
Marta Saraiva	Sandvik Coromant, Sweden
Jürgen Müller	Sulzer Metaplas GmbH, Germany
Jörg Paulitsch	Vienna University of Technology, Austria
Markus Pohler	CERATIZIT Austria GmbH, Austria

