The workshop took place between September 2-6 2018, in the Vadstena Klosterhotell, Vadstena, Sweden. The hotel is situated on the grounds previously held by the nuns of the Bridgettine Order. The workshop attracted a large number of participants, 74, from 17 countries: Sweden, China, Germany, Austria, USA, France, Israel, Czech Republic, Bulgaria, Taiwan, Lebanon, Hungary, Japan, Slovakia, Mexico, UK, and Liechtenstein. The program included 16 invited speakers and 21 contributed talks. A very lively poster session included 13 presentations. There was plenty of discussion time after each presentation and in two separate sessions. The workshop was chaired by Johanna Rosen johanna.rosen@liu.se, Ivan Petrov petrov@illinois.edu, Joe Greene jegreene@illinois.edu, and Jens Birch jens.birch@liu.se. The event was sponsored by Linköping University, Knut and Alice Wallenberg Foundation, Plansee, IHI group Ion Bond, and Vetenskapradet. The attendees enjoyed the beautiful historic city of Vadstena at Lake Vättern with a most perfect Swedish summer weather. The social program included a welcome reception, a guided tour of the medieval city and cloisters, a pleasant dinner, and a theatrical night tour of the Vadstena Castle.

The workshop focused on the synthesis, properties, defect structure, first-principles design, and applications of boron-containing protective and functional thin films and coatings. The sessions involved the following topics:

- Modelling and simulation of structure/property relationships for novel B-containing materials
- Control of nanostructure/composition during PVD and CVD synthesis
- Synthesis of targets for arc and magnetron sputtering; new precursors for CVD
- Challenges for quantitative characterization of B-containing coatings
- Protective coatings: hard, wear-, corrosion-, low-friction, and high-temperature applications
- Coatings for x-ray and neutron detectors and optics
VADSTENA, near Linkoping, Sweden
September 2-5, 2018

Chairs:
Johanna Rosen
Joe Greene
Ivan Petrov
petrov@illinois.edu

www.boronliu.com
The aim of this workshop is to initiate an in-depth discussion covering a broad range of boron-containing materials and synthesis technologies including approaches such as PVD and CVD to more complex methodologies incorporating gas- and/or power-pulsing techniques, presented in a systematic fashion, by key scientific groups worldwide.

The topics:
• Modelling and simulation of structure/property relationships for novel B-containing materials
• Control of nanostructure/composition during PVD and CVD synthesis
• Challenges for manufacturing boride sputtering targets and arc cathodes
• New precursors for CVD
• Challenges for quantitative characterization of B-containing coatings
• Protective coatings: hard, wear-, corrosion-, low-friction, and high-temperature applications
• Coatings for x-ray and neutron detectors and optics

The conclusion of the workshop is that boride/boron-containing coatings have emerged as the next generation of hard, wear-, oxidation- and corrosion-resistant coatings with many leading research groups dedicating significant effort in this area and making rapid progress. There was a general agreement to revisit this topic with a workshop in two years.
Some numbers and features

Number of participants 74
17 countries: Sweden, China, Germany, Austria, USA, France, Israel, Czech Republic, Bulgaria, Taiwan, Lebanon, Hungary, Japan, Slovakia, Mexico, UK, and Liechtenstein.
16 invited speakers
21 contributed talks.
13 poster presentations.

Sponsors: Linköping University, Knut and Alice Wallenberg Foundation, Plansee, IHI group Ion Bond, and Vetenskapradet

The attendees enjoyed the beautiful historic city of Vadstena at Lake Vättern with a most perfect Swedish summer weather.
The social program included a welcome reception, a guided tour of the medieval city and cloisters, a pleasant dinner, and a theatrical night tour of the Vadstena Castle.

Plenary lecture, Jan-Eric Sundgren, “Advanced Materials and Industrial Competitiveness through University-Business Cooperation”.
Joe Greene presented a science history lecture on “The 14-billion Year History of the Universe Leading to Modern Materials Science”
Ivan Petrov presented an overview of IUVSTA and its activities.
# 83rd IUVSTA Workshop Program

<table>
<thead>
<tr>
<th>SUNDAY</th>
<th>MONDAY</th>
<th>TUESDAY</th>
<th>WEDNESDAY</th>
<th>THURSDAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept 2</td>
<td>Sept 3</td>
<td>Sept 4</td>
<td>Sept 5</td>
<td>Sept 6</td>
</tr>
<tr>
<td>16:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registration opens</td>
<td>Opening</td>
<td>Schneider</td>
<td>Jansson</td>
<td>Mikula</td>
</tr>
<tr>
<td>19:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welcome reception</td>
<td>Plenary</td>
<td>Riedl</td>
<td>Chu</td>
<td>Houska</td>
</tr>
<tr>
<td></td>
<td>Sundgren</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zheng</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>COFFEE BREAK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polcik</td>
<td></td>
<td>Jilek Junior</td>
<td></td>
<td>Summary and Outlook</td>
</tr>
<tr>
<td>10:50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mayrhofer</td>
<td>Greeczynski</td>
<td>Höglund</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sochora</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:50</td>
<td>LUNCH AND NETWORKING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abelson</td>
<td>Wang</td>
<td>Ghafoor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vishnyakov</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chollon</td>
<td>Zhirkov</td>
<td>Wüstefeld</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tkadletz</td>
<td>Soucek</td>
<td>Alling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lee</td>
<td>Moraes</td>
<td>Campos-Silva</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15:10</td>
<td>COFFEE BREAK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15:40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vasina</td>
<td>DISCUSSION</td>
<td>Högberg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosen</td>
<td></td>
<td>Special Lecture</td>
<td>Greene</td>
<td></td>
</tr>
<tr>
<td>16:20</td>
<td></td>
<td>FREE TIME</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benke</td>
<td>FREE TIME</td>
<td>POSTER SESSION</td>
<td></td>
<td>FREE TIME</td>
</tr>
<tr>
<td>16:40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huang</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FREE TIME</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18:00</td>
<td>GUIDED TOUR</td>
<td>POSTER</td>
<td>18:40</td>
<td>GUIDED NIGHT TOUR AT THE CASTLE</td>
</tr>
<tr>
<td></td>
<td>SESSION</td>
<td></td>
<td>APERITIF</td>
<td></td>
</tr>
<tr>
<td>19:00</td>
<td>DINNER</td>
<td>DINNER</td>
<td>DINNER</td>
<td></td>
</tr>
</tbody>
</table>
# Financial report of the 83rd IUVSTA Workshop

## Income

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit cost (EUR)</th>
<th>Quantity</th>
<th>Sub-Total (EUR)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration Fee (per person, full fee)</td>
<td>790</td>
<td>58</td>
<td>45,820</td>
<td>73 registered participants, 58 paying full fee</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>10</td>
<td>5,000</td>
<td>10 invited speakers with reduced fee (6 paying no fee)</td>
</tr>
<tr>
<td>Sponsors</td>
<td>700</td>
<td>2</td>
<td>1,400</td>
<td>IHI group Ionbond and Plansee</td>
</tr>
<tr>
<td>VR funding</td>
<td>14,000</td>
<td>1</td>
<td>14,000</td>
<td>Conference grant from the Swedish Research Council (VR)</td>
</tr>
<tr>
<td>IUVSTA funding</td>
<td>6,000</td>
<td>1</td>
<td>6,000</td>
<td>Funding support for invited speakers</td>
</tr>
<tr>
<td><strong>Total (EUR)</strong></td>
<td></td>
<td></td>
<td>72,220</td>
<td></td>
</tr>
</tbody>
</table>

## Expenditures

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit cost (EUR)</th>
<th>Quantity</th>
<th>Sub-Total (EUR)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting rooms and food (2-6 Sept)</td>
<td>19,700</td>
<td>1</td>
<td>19,700</td>
<td>Lunch, (conference-) dinner, and coffee (twice per day)</td>
</tr>
<tr>
<td>Guided tours (Monday lunch + Wednesday night)</td>
<td>1,990</td>
<td>1</td>
<td>1,990</td>
<td></td>
</tr>
<tr>
<td>Hotel rooms (4 nights per invited speaker)</td>
<td>748</td>
<td>15</td>
<td>11,220</td>
<td></td>
</tr>
<tr>
<td>Hotel rooms for all other attendees (4 nights per person)</td>
<td>748</td>
<td>50</td>
<td>37,400</td>
<td>8 people did not need accommodation</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1,910</td>
<td>1</td>
<td>1,910</td>
<td>Bus/Taxi for speakers, Poster session (incl. drinks), etc.</td>
</tr>
<tr>
<td><strong>Total (EUR)</strong></td>
<td></td>
<td></td>
<td>72,220</td>
<td></td>
</tr>
</tbody>
</table>
Challenges for manufacturing boride sputtering targets and arc cathodes

At the opening, Ivan Petrov presented an overview of IUVSTA and its activities. We had a very high calibre plenary speaker, Jan-Eric Sundgren, who delivered a lecture entitled “Advanced Materials and Industrial Competitiveness through University-Business Cooperation”.

The section on modelling and simulation was very strong with invited talks by Jochen Scheider and Michael Widom and several contributed talks, including by Björn Alling, Vincent Moraes, and others. It became apparent that there is a concerted effort in the community to use ab-initio calculation in the search for novel B-containing coatings, which guide experimental work on the synthesis of novel materials. An entire family of metastable diborides has emerged with the potential for age hardening during use.

Another section of talks was devoted to CVD, lead by the invited talk of John Abelson who focused on a novel family of precursors developed for low-temperature (<300 °C) deposition routes of transition metal diboride films with superconformal coverage for diffusion-barrier, low-friction, and oxidation-resistant applications.

The majority of the presentations covered PVD synthesis of a wide-range of compositions of B-containing coatings deposited my DCMS, HiPIMS, and cathodic arc. This is an extremely active field experiencing rapid progress. One of the challenges is to find ways to control the B to metal ratio which is a challenge because unlike reactive sputtering of nitride, oxides, and carbides, there are no non-toxic reactive gases. Several techniques to control the B-content in the films were outlined, all involving using differences in the ionization cross-section of Boron and the transition metals. Powder-pack boriding to produce boride coatings on AISI 316 L steel and CoCrMo alloys for tribological and biomedical applications was covered by Ivan Campos and colleagues.

While most of the PVD research targets novel protective coating, Carina Höglund described the research, development, and the industrialization of a process to deposit $^{10}$B$_4$C thin films for neutron detection. Peter Polcik presented an invited talk describing the active research conducted at Plansee to overcome challenges in manufacturing high quality, pure diboride targets with almost all transition metals.
A series of talks were devoted to the specifics of quantitative characterization of B-containing coatings by TEM (Per Persson), XPS, EDX, and WDS (Vladimir Vishnyakov) and XPS, XRD, XANES, and EXAFS (Martin Magnusson).

Joe Greene presented a science history lecture on “The 14-billion Year History of the Universe Leading to Modern Materials Science”.

The overall conclusion of the workshop is that boride/boron-containing coatings have emerged as the next generation of hard, wear-, oxidation- and corrosion-resistant coatings with many leading research groups dedicating significant effort in this area and making rapid progress. There was a general agreement to revisit this topic with a workshop in two years.

The IUVSTA funds for the 83rd IUVSTA Workshop of 6000 Euros were used to cover partially the costs for workshop registration and accommodation for the invited speakers, as specified in detail in the financial report. The overall workshop budget was break-even.

Photos from the workshop can be seen here:

https://ivanp.smugmug.com/Other/83rd-ICMCTF-workshop-in-Vadstena-Sweden/

83rd IUVSTA workshop group photo
The Plenary lecture by Jan-Eric Sundgren

A very lively poster session

The theatrical night tour of the Vadstena castle
LIST OF ATTENDEES

*Invited speakers are highlighted in bold*

Jan-Eric Sundgren, EIT RawMaterials eV and the Swedish Association of Engineering Industries, Sweden
Ulf Karlsson, Linköping University, Sweden

Weitao Zheng, Jilin University, China

Peter Polcik, Plansee Composite Materials GmbH, Germany

Lars Hultman, Swedish Foundation for Strategic Research, Sweden

Paul Mayrhofer, TU Wien, Austria

John Abelson, University of Illinois, USA

Greger Håkansson, Ionbond, Sweden

Georges Chollon, University of Bordeaux, France

Sören Kahl, Husqvarna, Sweden

Anton Nikitin, Iscar, Israel

Michael Tkadletz, Montanuniversität Leoben, Austria

Mojmir Jilek, PLATIT, Czech Republic

Lars Johnson, Sandvik Coromant, Sweden

Mats Johansson-Jöesaar, Seco Tools, Sweden

Carl Björmander, Sandvik Coromant, Sweden

Jyh-Wei Lee, Ming Chi University of Technology, Taiwan

Petr Vasina, Masaryk University, Czech Republic

Linda Robinson, European Spallation Source ERIC, Sweden

Per-Olof Svensson, European Spallation Source ERIC, Sweden

Chung-Chuan Lai, European Spallation Source ERIC, Sweden

Johanna Rosen, Linköping University, Sweden

Biljana Mesic, SemeCon AG, Germany

Roman Motyka, IBC Coatings Technologies Inc., Lebanon

Peter Harper, IBC Coatings Technologies Inc., Lebanon

Fredrik Eriksson, Linköping University, Sweden

Per Eklund, Linköping University, Sweden

Justinas Palisaitis, Linköping University, Sweden

Ivan Petrov, University of Illinois, USA

Joe Greene, University of Illinois, USA

Jens Birch, Linköping University, Sweden

Feng Huang, Ningbo Institute of Materials Technology and Engineering, China

Marton Benke, University of Miskolc, Hungary

Babak Bakhit, Linköping University, Sweden

Bih-Show Lou, Chang Gung University, Taiwan
Christina Kainz, Montanuniversität Leoben, Austria
Claudia Schnitter, Linköping University, Sweden
Stanislava Debnárová, Masaryk University, Czech Republic
Sjoerd Broekhuijsen, Linköping University, Sweden
Takuya Ishihara, Azbil Corporation, Japan
Laurent Souqui, Linköping University, Sweden
Jiahao Weng, Ningbo Institute of Materials Technology and Engineering, China
Branislav Grancic, Comenius University in Bratislava, Slovakia
Tetsuhide Shimizu, Tokyo Metropolitan University, Japan,
Jimmy Thörnberg, Linköping University, Sweden
Erik Johansson, Linköping University, Sweden
Jochen Schneider, RWTH Aachen University, Germany
Helmut Riedl, TU Wien, Austria
José Martínez Trinidad, Instituto Politécnico Nacional, Mexico
Mojmir Jilek Junior, PLATIT, Czech Republic
Grzegorz Greczynski, Linköping University, Sweden
Vjaceslav Sochora, SHM, Czech Republic
Marian Mikula, Comenius University in Bratislava, Slovakia
Pavel Soucek, Masaryk University, Czech Republic
Vincent Moraes, TU Wien, Austria
Igor Zhirkov, Linköping University, Sweden
Ai-Ying Wang, Ningbo Institute of Materials Technology and Engineering, China
Hans Högberg, Linköping University, Sweden
Vladimir Vishnyakov, University of Huddersfield, UK
Ulf Jansson, Uppsala University, Sweden
Jinn P. Chu, National Taiwan University of Science and Technology, Taiwan
Per O.Å. Persson, Linköping University, Sweden
Michael Widom, Carnegie Mellon University, USA
Carina Höglund, European Spallation Source ERIC, Sweden
Naureen Ghafoor, Linköping University, Sweden
Christina Wüstefeld, Technische Universität Bergakademie Freiberg, Germany
Björn Alling, Linköping University, Sweden
Ivan E. Campos-Silva, Instituto Politécnico Nacional, Mexico,
Jiri Houska, University of West Bohemia, Czech Republic
Martin Magnusson, Linköping University, Sweden
Anders Eriksson, Oerlikon, Liechtenstein
Kan Zhang, Jilin University, China
Henrik Pedersen, Linköping University, Sweden
Xiao Zuo, Ningbo Institute of Materials Technology and Engineering, China
SCHEDULE

Names in **bold**: 40 minutes
Names in *italic*: 20 minutes

SUNDAY

Arrival, registration from 16.00. Welcome reception at 19.00.

MONDAY

Plenary speaker:  
Jan-Erik Sundgren  Advanced Materials and Industrial competitiveness through University-Business Cooperation

Session:  
**Weitao Zheng** Exploring the novel B-containing superhard materials in extreme condition

**Peter Polcik** Boride sputtering targets and arc cathodes – Challenges for manufacturing technologies and target/cathode design

**Paul Mayrhofer** Interface and interphase controlled properties of transition metal borides: The beauty of imperfections

**John Abelson** CVD of Transition Metal Diborides Below 300°C: Routes to Conformal, Superconformal, Hard, Low-friction and Oxidation-resistant Coatings

**Georges Chollon** Structure and thermal stability of (Si)-B-C ceramics synthesized by chemical vapor deposition

**Michael Tkadletz** Investigation of microstructure and mechanical properties of CVD-Ti(N,B) coatings with varying B content

**Jyh-Wei Lee** Microstructure and mechanical property evaluation of boron-contained TiZrBN hard coatings

**Petr Vasina** Influence of chemical composition on structure and mechanical properties of W-B-C coating deposited in industrial sputtering system

**Johanna Rosen** TiB\(_2\) synthesis from optimized arc and sputtering methods

**Marton Benke** Application of TiB\(_2\) for soldering applications

**Feng Huang** Enhancing deformability of TiB\(_2\)-based hard coatings via proper metal addition

Guided tour “A historical odyssey”.

Dinner

TUESDAY

**Jochen Schneider** Quantum mechanically guided design of borides or experimentally guided quantum mechanical calculations?

**Helmut Riedl** Synthesis of W\(_{1+x}\)M\(_x\)B\(_2\) based ternary diborides: Challenges and Possibilities

**José Martinez Trinidad** In-vitro cytotoxicity of iron boride layers

**Mojmir Jilek Junior** Wear-resistant, nanostructured boron containing PVD coatings for industrial use

**Grzegorz Greczynski** (Preliminary title:) Plasma characterization and thin film synthesis - HfB\(_2\)

**Vjaceslav Sochora** Me-BN coatings simultaneously deposited by cathodic arc and magnetron sputtering
Lunch and networking

Ai-Ying Wang  Superhard yet tough CrB\textsubscript{2} coating with superior corrosion resistance deposited by DC magnetron sputtering
Vladimir Vishnyakov  Boron quantification, a comparison between different analysis techniques
Igor Zhirkov  Characterization of plasma generated in magnetron sputtering from metal boride targets
Pavel Soucek  Novel coatings with high hardness and fracture resistance based on metal-carbon-boron design
Vincent Moraes  Ab-initio driven design of ternary diboride thin films

Coffee break

Discussion

Poster session

Dinner

WEDNESDAY

Ulf Jansson  Ternary nanolaminated borides – aspects of growth and properties
Jinn Chu  Boron-containing metallic-glass coating for the first-ever metallic nanotube array
Per Persson  Advanced electron microscopy of borides

Coffee break

Michael Widom  Mixed and partial site occupancy in boron and its carbides and nitrides
Carina Höglund  \( ^{10}\text{B}4\text{C} \) thin films for neutron detection

Lunch and networking

Naureen Ghafoor  Impact of B+C co-sputtering on structure and optical performance of multilayer X-ray mirrors
Christina Wüstefeld  Microstructure of Ti-B-C-N nanocomposites deposited from Ti and B+C targets
Björn Alling  Theoretical investigations of mixing thermodynamics, age-hardening potential, and electronic structure of boride alloys
Ivan Campos-Silva  The boriding process to improve the tribocorrosion resistance of metallic biomaterials

Coffee break

Hans Höberg  Thin film synthesis and characterization of ZrB\textsubscript{2}

Special Lecture

Joe Greene  The 14-billion Year History of the Universe Leading to Modern Materials Science

Aperitif

Dinner

Guided night tour “Night patrol at Vadstena Castle”

THURSDAY

Marian Mikula  Structure evolution and mechanical properties of yttrium based ternary diborides
Jiri Houska  Role of boron in amorphous SiBCN and nanocomposite MSiBCN
Martin Magnusson  Structure Properties of Transition Metal Borides Investigated by Xray Spectroscopy

Coffee break

Summary and Outlook