

**SCIENTIFIC AND METHOD MODULES**

<b>Module name</b>	<b>From Molecules to Materials</b> Transparent Conductive Oxides – Fundamentals and Applications
<b>Number</b>	2014-T4
<b>Aims</b>	The material class of transparent conductive materials has been discovered 1907 by Karl W. Baedeker in Leipzig. This module focuses on modern transparent functional materials, from their basic material physics to applications
<b>Basics</b>	covered in basic modules B1–B3, solid state physics, wide gap materials
<b>Contents</b>	The fundamental solid state aspects include defect formation in such materials (for few if any defects, a correlation between experimental physical defects properties and microscopic defect structure exist), the electronic band structure theory (LDA is not a good approximation for such metal oxides) and p-type doping (which is notoriously difficult for many oxides). Research on bulk properties has been promoted by the availability of substrates and/or bulk crystals for a number of oxides (ZnO for a while, recently Ga <sub>2</sub> O <sub>3</sub> ). From an application point of view, materials with larger mobility (at high carrier concentration), materials from earth abundant materials (avoiding expensive and noble metals), materials suitable for low temperature fabrication (in order to reduce the energy budget of industrial processes, process compatibility with flexible electronics), and amorphous materials (for flexible electronics and also room temperature deposition) are desirable.
<b>Methods</b>	Thin film deposition, optical and electrical characterization, device processing, however module has no focus on methodological aspects.
<b>Type</b>	Two-day block course
<b>Date (month/year)</b>	29 September to 2 October 2014 (two days, 3 or 4 days optional)
<b>Time</b>	See program: <a href="http://www.uni-leipzig.de/~hlp/TCO2014/program.html">http://www.uni-leipzig.de/~hlp/TCO2014/program.html</a>
<b>Work load</b>	15 hours presence/ 45 hours self-study
<b>Examination</b>	Oral
<b>Credit points</b>	2
<b>Responsible scientists</b>	Grundmann
<b>International guest lecturers</b>	K. Butler (University of Bath, UK), D. Ehrentraut (SORAA AMERICAS, Fremont, USA), Kee Hoon Kim (Seoul National University, Republic of Korea), J. F. Wager (Oregon State University, USA), L. Piper (Binghamton University, USA), S. Lany (NREL, USA), L. J. Brillson (Ohio State University, USA), D.C. Look (Wright State University, USA), M. Allen (University of Canterbury, New Zealand), E. Fortunato (University of Lisbon, Portugal)
<b>Industrial partners</b>	Solarion AG
<b>Recommendations for literature, e-learning</b>	Transparent Electronics: From Synthesis to Applications, Editor: ANTONIO FACCHETTI and TOBIN J. MARKS, John Wiley & Sons Ltd, 2010; Handbook of Transparent Conductors, Editor: David S. Ginley, Hideo Hosono, David C. Paine, Springer Science and Business Media, 2010; Transparent Electronics, Autor: J.F. Wager, D.A. Keszler, R.E. Presley, Springer Verlag, 2008; Springer Series in Materials Science 104, Transparent Conductive Zinc Oxide, Basics and Applications in Thin Film Solar Cells, Editor: Klaus Ellmer, Andreas Klein, Bernd Rech, Springer Verlag 2008

# TGO 2014

BuildMoNa Module 2014-T04  
From Molecules to Materials

## Transparent Conductive Oxides – Fundamentals and Applications

Monday, 29 September to Thursday, 2 October 2014  
Universität Leipzig, 04103 Leipzig, Linnéstr. 5,  
Lecture Hall for Theoretical Physics

### Agenda

#### Monday, 29 September 2014

- 13:30 Prof. Dr. Marius Grundmann  
Universität Leipzig  
*Opening*
- 14:00 Prof. Dr. Christian Elsässer\*  
Fraunhofer IWM, Freiburg, Germany  
*Electronic-structure theory of amorphous transparent (semi-)conducting oxides*
- 14:45 Jörg Haeberle  
Brandenburgische TU Cottbus, Germany  
*The electronic structure of amorphous SnO<sub>x</sub> and SnO<sub>2</sub> single crystals*
- 15:00 Prof. Dr. Friedhelm Bechstedt\*  
Friedrich-Schiller-Universität Jena, Germany  
*Transparent conducting oxides: Electronic states and band line-ups from first principles*
- 15:30 *Coffee break (Aula)*
- 16:00 Dr. Keith T. Butler\*  
University of Bath, UK  
*Beyond the bulk: Modelling surfaces and interfaces of transparent conducting oxides*

---

\* invited talk



**BuildMoNa**

UNIVERSITÄT LEIPZIG

- 16:45 Prof. Dr. Werner Mader  
-- Universität Bonn, Germany  
17:15 *Layered oxide compounds as transparent electronics*
- 19:00 Welcome reception and Dinner (Ratskeller)

**Tuesday, 30 September 2014**

- 9:00 Prof. Dr. Axel Hoffmann\*  
TU Berlin, Germany  
*Optical Properties in transparent conductive semiconductors*
- 9:45 Patrick Vogt  
Paul-Drude-Institut Berlin, Germany  
*Epitaxial relation and growth-kinetics study of  $In_2O_3$  and  $\beta-Ga_2O_3$  ( $\bar{2}01$ ) on rhombohedral  $Al_2O_3$  (0001)*
- 10:15 Prof. Dr. Michael Lorenz  
Universität Leipzig, Germany  
*Performance and limitations of pulsed laser deposition of transparent conducting thin films*
- 10:45 *Coffee break (Aula)*
- 11:15 Dr. Zbigniew Galazka\*  
Institut für Kristallzüchtung, Berlin, Germany  
*Czochralski growth, characterization and properties of  $\beta-Ga_2O_3$  single crystals*
- 12:00 Dr. Heiko Frenzel  
Universität Leipzig, Germany  
*Long-throw magnetron sputtering of amorphous Zn-Sn-O thin films*
- 12:15 Dr. Günter Wagner  
Institut für Kristallzüchtung Berlin, Germany  
 *$Ga_2O_3$  and  $(Ga_{1-x}In_x)_2O_3$  layers on  $\beta-Ga_2O_3$ (100) grown by metal organic vapor phase epitaxy*
- 12:45 *Lunch (Aula)*
- 14:15 Dr. Stephan Lany\*  
NREL, USA  
*Computational design of wide gap materials*
- 15:00 Nicole Karpensky  
Helmholtz-Zentrum Berlin, Germany  
*Optical investigation of localized defects in zinc oxide*



- 15:15 Christian Kranert  
Universität Leipzig, Germany  
*Phonon modes and structural properties of  $(\text{In,Ga})_2\text{O}_3$  thin films*
- 15:30 *Coffee break (Aula)*
- 16:00 Prof. Leonard J. Brillson\*  
Ohio State University, USA  
*Native point defect energies, densities, and electrostatic repulsion across MgZnO alloys*
- 16:45 PD Dr. Eduard V. Lavrov\*  
TU Dresden, Germany  
*Hydrogen in ZnO and rutile  $\text{TiO}_2$*
- 17:15 Dr. Marc A. Gluba  
Helmholtz-Zentrum Berlin, Germany  
*Self-diffusion on polar and non-polar zinc oxide surfaces*
- 17:45 Group photo shooting (in front of main building)
- 18:00 Poster Session (TA307)

**Wednesday, 1 October 2014**

- 9:30 Prof. Dr. John F. Wager\*  
Oregon State University, USA  
*Flat-panel display backplanes: LTPS or IGZO for AMLCDs or AMOLEDs?*
- 10:15 *Coffee break (Aula)*
- 11:00 Dr. Silma Alberton Corrêa  
Brandenburgische TU Cottbus, Germany  
*Evaluation of the band gap of  $\text{HfO}_2$  thin films deposited by atomic layer deposition*
- 11:15 Dr. Louis Piper\*  
Binghamton University, USA  
*Electrical conductivity without sacrificing optical transparency in a-IGZO*
- 12:00 Peter Schlupp  
Universität Leipzig, Germany  
*All amorphous bipolar heterodiodes consisting of n-type zinc-tin oxide and p-type zinc-cobalt oxide*
- 12:30 *Lunch (Aula)*



## BuildMoNa

- 14:00 Prof. Dr. Kee Hoon Kim\*  
Seoul National University, Republic of Korea  
*Physical properties of doped BaSnO<sub>3</sub> semiconductors with high electrical mobility and optical transparency at room temperature*
- 14:45 Robert Karsthof  
Universität Leipzig, Germany  
*Doped nickel oxides as p-type TCO*
- 15:00 Christian Koppka  
TU Ilmenau, Germany  
*MOCVD-growth and characterization of AZO-contacts for p-doped GaAs nanowire structures*
- 15:15 Alexander Shkurmanov  
Universität Leipzig, Germany  
*Low temperature PLD-growth of ZnO nanowires*
- 15:30 *Coffee break (Aula)*
- 16:00 Prof. Dr. Bernd Szyszka\*  
TU Berlin, Germany  
*Multi component TCO films by hollow cathode gas flow sputtering*
- 16:45 Friedrich-L. Schein  
Universität Leipzig, Germany  
*Transparent p-CuI/n-ZnO heterjunction diodes*
- 17:15 Prof. Dr. Bruno K. Meyer\*  
--  
Justus Liebig Universität Gießen, Germany
- 18:00 *Copper oxides: Materials properties and photovoltaic devices*
- 20:00 Prize Ceremony and Conference Banquet (Bayrischer Bahnhof)

### Thursday, 2 October 2014

- 9:00 Dr. André Bikowski\*  
Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany  
*The influence of Mg on the structural and electrical properties of magnetron sputtered Zn<sub>1-x</sub>Mg<sub>x</sub>O:Al thin films*
- 9:45 Abdurashid Mavlonov  
Universität Leipzig, Germany  
*Investigation of dopant limitations in Mg<sub>x</sub>Zn<sub>1-x</sub>O:Al, Ga (0 ≤ x ≤ 0.1)*
- 10:00 Jakob Nixdorf  
Otto-von-Guericke-Universität Magdeburg, Germany  
*Carrier density dependent effective electron mass in cubic In<sub>2</sub>O<sub>3</sub>*



- 10:15      *Coffee break (Aula)*
- 11:00      Dr. David C. Look\*  
Wright State University, USA  
*Large-area, nondestructive mapping of thickness, mobility, concentration, dopant, and compensator in Ga-doped ZnO films*
- 11:45      Christian Lidig  
Otto-von-Guericke-Universität Magdeburg, Germany  
*Anisotropic dielectric function and effective electron masses of rutile SnO<sub>2</sub>*
- 12:00      Dr. Sergey Sadofev  
Humboldt-Universität Berlin, Germany  
*Free electron density and polarity inversion domains in plasmonic (Zn,Ga)O*
- 12:30      *Lunch (Aula)*
- 14:00      Prof. Dr. Martin Allen\*  
University of Canterbury, New Zealand  
*Unipolar devices based on ZnO (and related materials)*
- 14:45      Kevin A. Stewart  
Oregon State University, USA  
*Effect of ultrathin channel layers on the properties of amorphous Al-In-Sn-O TFTs*
- 15:00      Daniel Splith  
Universität Leipzig, Germany  
*Schottky contacts on  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> thin films grown by pulsed laser deposition*
- 15:15      Zhipeng Zhang  
Universität Leipzig, Germany  
*Ultraviolet photodiodes based on (Mg,Zn)O and (Ga,In)<sub>2</sub>O<sub>3</sub> thin films*
- 15:30      *Coffee break (Aula)*
- 16:00      Prof. Dr. Elvira Fortunato\*  
University of Lisbon, Portugal  
*Transparent complementary electronics*
- 16:45      Prof. Dr. Marius Grundmann  
Universität Leipzig  
*Closing*
- 17:00      Prospective end