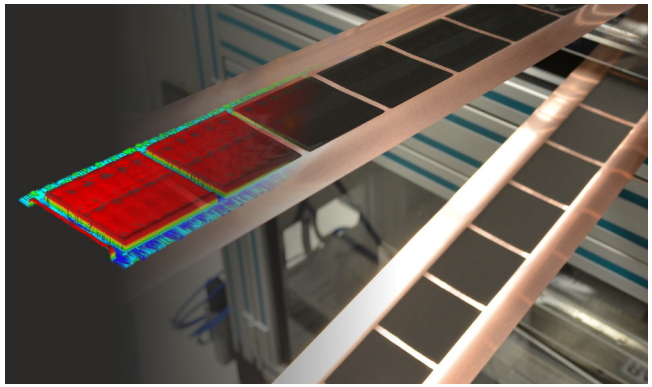
DECHEMA-Gesellschaft für Chemische Technik
und Biotechnologie e.V.

DECHEMA GVT

TFT
Thin Film Technology

# 10th Short Course
# Coating and Drying of Thin Films

3(+2)-day short course on fundamentals and applications with practical workshop in the coating and printing lab



# 3rd Thin Film Technology Forum

2-day forum on June 7-8 on advances in Printed Electronics, Battery and Smart Coatings

**June 4-8, 2018**

**KIT-Tagungszentrum (FTU)**

**Hermann-von-Helmholtz-Platz 1**
**76344 Eggenstein-Leopoldshafen**

Organisation: Prof. Dr.-Ing. Wilhelm Schabel
Dr.-Ing. Philip Scharfer
with 20 experts from industry and academia

# Program Short Course and Forum

30 contributions from 27 speakers (18 external)

## Schedule 04.06.2018 – Short Course Monday

**12:00** *Registration and hand out of course material*
**12:30** *Welcome and introduction*
Prof. Dr.-Ing. W. Schabel / Dr.-Ing. P. Scharfer
**13:15** *Coating and printing fluids characterisation*
Dipl.-Ing. Gilbert Gugler (iPrint, CH)
**14:30** *Coffee break*
**15:00** *Rheology of coating fluids*
Prof. Dr. Norbert Willenbacher (KIT)
**16:15** *Introduction to self- and premetered coating*
Dr. Peter Schweizer (Fribourg, CH)

**19:30** *Social dinner at BESITOS (Karlsruhe town square)*

## Schedule 05.06.2018 – Short Course Tuesday

**09:00** *Curtain and slot die coating*
Dr. Peter Schweizer (Fribourg, CH)
**10:00** *Coffee break*
**10:30** *Fluid flow in coating tools*
Prof. Dr. Dr. h. c. mult. Franz Durst (FMP)
**11:30** *Knife and blade coating*
Prof. Dr. Hadj Benkreira (University of Bradford, UK)
**12:30** *Lunch break*
**13:30** *Gravure and roll coating*
Prof. Dr. Hadj Benkreira (University of Bradford, UK)
**14:30** *Coffee break*
**15:00** *Fundamentals of drying technology*
Prof. Dr.-Ing. Wilhelm Schabel (KIT)
**16:15** *Coffee break*
**16:30** *Film drying and drying studies*
Prof. Dr.-Ing. Wilhelm Schabel (KIT)

## Schedule 06.06.2018 – Short Course Wednesday

**08:30** *Drying of particulate coatings and crack formation*
Dr. Alex Routh (Cambridge, UK)
**10:00** *Sorption equilibrium in polymeric films*
Tobias Fritzensmeier M. Sc. (KIT)
**10:20** *Coffee break*
**10:50** *Sorption equilibrium in porous films*
Jochen Eser M. Sc. (KIT)
**11:10** *Simulation & design of industrial thin film dryers*
Dr.-Ing. Philip Scharfer (KIT)
**12:40** *Lunch break*
**13:40** *Homogeneous drying with comb nozzles*
Dipl.-Ing. Philipp Cavadini (CN Drying Technology UG)
**14:10** *Industrial perspectives of slot die coating*
Dipl.-Ing. Harald Döll (TSE, CH)
**14:40** **Coffee break**
**15:10** *Industrial perspectives of coating and converting*
Florian Lemm (Kroenert)
**15:40** *Applications of NIR-Drying Technology*
Dr. Kai K. O. Bär (adphos Digital Printing GmbH)
**16:10** *Coating, drying and web handling apps*
Prof. Dr. Steven Abbott (TCNF, UK)

## Schedule 07.06.2018 – Short Course & Forum Thursday

**09:00** *Experimental workshop at the TFT coating and printing laboratory*
*- Characterisation of material systems*
*- Pilot-scale coating trials*
*- Heat and mass transfer coefficients*
*- Experimental drying curves*

**13:00** *TFT Forum get-together lunch (Finger Food)*

**14:00** *Welcome & Introduction to TFT Forum*
Prof. Dr.-Ing. W. Schabel / Dr.-Ing. P. Scharfer
**14:10** *Welcome & Introduction to KIT*
Prof. Dr. Doris Wedlich (KIT)
Head of Division 1 (Biology, Chemistry, Proc. Engineering)
**14:20** *Advances in organic & printed electronics processing*
Ir. Ike de Vries (Holst Centre, NL)
**15:10** *Multilayer coating of organic electronics*
Lisa Merklein M. Sc. (KIT)
**15:40** *Coffee break*
**16:10** *Advances in digital direct printing*
Prof. Fritz Bircher (iPrint, CH)
**17:00** *Inks for printed, soft, and transparent electronics*
Prof. Dr. Tobias Kraus (Leibniz-Institut für Neue Materialien)

**19:30** *Get-together at BESITOS (Karlsruhe town square)*

## Schedule 08.06.2018 – Short Course & Forum Friday

**09:00** *Battery technologies beyond Li-Ion technology*
Prof. Dr. Stefano Passerini (Helmholtz-Institut Ulm)
**09:30** *Industrial production of lithium-ion battery cells*
Dr. Armin Modlinger (Volkswagen AG)
**10:00** *Advances in coating of Li-Ion battery electrodes*
Dipl.-Ing. Ralf Diehm (KIT)
**10:30** *New insights into drying of Li-Ion battery electrodes*
Jana Kumberg M. Sc. (KIT)
**11:00** *Coffee break*
**11:30** *Applications in solution-processed functional films*
Prof. Dr. Frank Kleine Jäger (BASF SE)
**12:00** *Drying of thin films of particle-laden pastes*
Prof. Dr.-Ing. Günter Brenn (TU Graz, AT)
**12:30** *Enabling mobility for tomorrow with surface technology*
Dipl.-Ing Milan Madron (Schaeffler AG)
**13:00** *Graphene dispersions for conductive paints*
Dr. Katerina Kampioti (CNRS Bordeaux, FR)
**13:30** *TFT Forum closing session lunch (Finger Food)*

## Introduction

The short course Coating and Drying of Thin Films addresses engineers, scientists and technicians working in the areas of coatings, functional films, direct printing, inkjet printing, sensors, adhesives, paints, automotive coatings, patches, optical foils, tapes, diagnostics, membranes, printed electronics, fuel cells and battery coatings, who intend to get insight into more fundamental aspects with industrial applications or to deepen their expertise. Leading national and international scientists and experts from academia and industry will report on topics of coating technologies, rheology, preparation of coating fluids and about fundamentals and industrial aspects of drying technology. Coating and printing processes and drying technology are explained interactively by easily accessible examples and in a practical workshop in the TFT Coating and Printing Lab instructed by TFT staff members (see photos below).

The 3rd Thin Film Technology Forum will take place on the 4th and 5th day, where renowned scientists will present and discuss new trends in industry and academia with a focus on Printed Electronics, Battery and Smart Coatings.

## Registration fees

| | Early Bird (until 01.04.18) | later |
|---|---|---|
| General | € 1625.– | € 1775.– |
| GVT discount | € 1575.– | € 1725.– |
| Exhibition booth | € 950.– | € 1100.– |

## Payment

According to §4 Nr. 22a USTG the registration fee is purchase tax free. Registration fees include a short course folder with documentation of lectures and workshop, coffee, refreshments, lunch and social dinner on Monday evening and the TFT Forum get-together on Thursday evening. A participation certificate will be distributed.

## Venue

The short course takes place at the KIT-Tagungszentrum (FTU), Seminarraum 157, Hermann-von-Helmholtz-Platz 1 in 76344 Eggenstein-Leopoldshafen.

## Hotel recommendations

Hotel Kaiserhof, Hotel Novotel Karlsruhe City,
City Partner Hotel Berliner Hof, Hotel Rio

## Further information

www.tft.kit.edu – TFT Courses

## Feedback about the last TFT courses

- "Excellent introduction in coating and drying of films. Demonstrates the complexity, offers better understanding of processes."
- "Very interesting course, lots of information on all coating application! Building bridge from university to industrial applications."
- "Well built-up structure, wide range of theory and application covered, too short time for discussion/break."
- "High level talks with broad range of topics but with good scientific and practical depth, also on application."
- "Good structure."

## and workshop

- "Good to see how the theory of the courses works in real life"
- "Experiments were very well prepared and perfectly organized"
- "Interesting, well organized"

## Further information and registration:

http://www.tft.kit.edu/745.php
http://www.gvt.org/Hochschulkurse.html

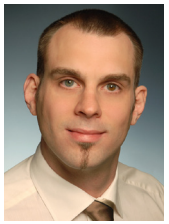
## Contact

Registration:
Anna-Maria Hipp: gvt-hochschulkurse@gvt.org
Phone: +49 69 7564-118

Short course organisation:
Jana Kumberg M. Sc.: jana.kumberg@kit.edu

Office TFT: margit.morvay@kit.edu

**Prof. Dr.-Ing. Wilhelm Schabel (KIT)** heads the research group Thin Film Technology at KIT (Campus South/Campus North). He studied process engineering with a doctor thesis in the field of film drying, honored with the Carl-Freudenberg Award in 2005. In 2007-2008 he worked as R&D engineer at LOFO High Tech Film. In 2007 his work was honored with the Arnold Eucken Award, in 2008 with the L.E. Scriven Award from ISCST. Prof. Schabel is active in international drying, coating, processing and heat and mass transfer committees as chairman, director and vice president. He is an expert in film drying with coating expertise and (co-)author of more than 400 scientific contributions.



**Dr.-Ing. Philip Scharfer (KIT)** is head of the TFT group at KIT together with Prof. Schabel. He received his PhD in process engineering from the University of Karlsruhe (TH) in 2009. Dr. Scharfer is an expert in the fields of drying and thermodynamics of thin films. He deals with measuring methods for the investigation of polymer film drying and develops numerical simulation tools for industrial dryer applications. Since 2009, Dr. Scharfer is member of the scientific committee of the European Coating Symposium (ECS), since 2012 member of the Board of Directors of the International Society of Coating Science and Technology (ISCST). In 2014, he was awarded with the L. E. Scriven Young Investigator Award by the ISCST.

**Prof. Dr. Norbert Willenbacher (KIT)** is head of the Institute of Mechanical Process Engineering and Mechanics at Karlsruhe Institute of Technology (KIT) since 2004. He received his diploma degree in Physics and his PhD from the University of Mainz. After his dissertation at the Max-Planck-Institute for Polymer Research he joined BASF SE as a research associate in the fields of rheology of complex fluids and adhesion of soft polymers for 15 years. Prof. Willenbacher is president of the German Society of Rheology, assigned member of the ProcessNet Technical Committee on Rheology, and member of the Editorial Board of Rheologica Acta.

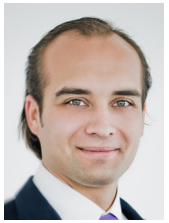
**Dr. Alex Routh (Cambridge University, UK)** received his PhD from Princeton University in the US in 2000. He has been lecturing in Chemical Engineering at the University of Cambridge since 2006 and was promoted to full professor in 2017. His position is a joint appointment with the BP Institute for Multi-Phase Flow; a multi-disciplinary research institute within the University, spanning the physical sciences. His research is in the field of colloid science and Prof Routh has worked in the areas of encapsulation, dispersion stability, formulation and drying. Within the film drying topic, he has been active for the past 15 years and has published extensively in the specifics of film cracking and the flows within thin films.

**Dipl.-Ing. ETH Gilbert Gugler (iPrint, CH)** received his diploma in material science from the ETH Zurich in 1992. From 1992 to 1998 he worked in the area of chemical and physical vapour deposition. From 1998 on, he worked at Ilford Imaging Switzerland GmbH. Leading the Technology Center of Wifag-Polytype Technologies AG since 2014 he was responsible for all coating and process related topics. End of 2016 he joined the university of applied science and arts of Western Switzerland as deputy managing director of the iPrint institute. Gilbert Gugler is an expert in multilayer curtain coating technology, starting from the preparation of coating fluids, characterization, processing, to the multilayer curtain coating and drying. Since 2017, he is heading his own company called Gugler Coatech Consulting.

**Dr. Peter M. Schweizer (Fribourg, CH)** received his PhD in Mechanical Engineering from the Swiss Federal Institute of Technology in 1979, and he did postdoctoral research in coating flows at the University of Minnesota with Prof. Scriven from 1979 – 1980. From 1981 – 1986, Dr. Schweizer worked in the Coating Flow Research Group at Kodak in Rochester, New York, and from 1987 – 1996, he worked at ILFORD in Fribourg, Switzerland. From 1997 – 2000, Dr. Schweizer was Managing Director of TSE Troller Schweizer Engineering in Switzerland. From 2001 - 2016, he worked for Polytype Converting in Fribourg, Switzerland. Since 2016, he is heading his own company called Schweizer Coating Consulting GmbH.

**Prof. Dr. Hadj Benkreira (Univ. of Bradford, UK)** (BEng, MSc Chemical Engineering) obtained his PhD on the Fluid Mechanics of Coating Flows in 1980 under the supervision of Professor WL Wilkinson (CBE, FRS). Following five years of EPSRC postdoctoral re¬search, he joined the academic staff of the Univer¬sity of Bradford in 1985 and was endowed a Personal Research Chair in 1998 for research in Thin Film Coating and in Polymer Processing and became in 2004-2009 Associate Dean for Research. Professor Benkreira is member of several learned societies including the UK EPSRC Peer Review College, the ISCST of which he was the Vice President in 2006-8 and the European Coating Symposia steering committee.

**Prof. Dr. Dr. h. c. mult. Franz Durst (FMP TECHNOLOGY GMBH)** graduated from Imperial College at the London University and received his doctor's degree in 1972 (PhD). In 1972, he returned to Germany and worked as subproject leader of various research projects at the Collaborative Research Center 80 at the University of Karlsruhe for ten years. Prof. Durst was offered a C3 professorship for Fluid Mechanics at the University of Karlsruhe in 1978 and was appointed chair of the Institute of Fluid Mechanics at the University of Erlangen-Nuremberg in 1982. In 2006, Prof. Durst retired from the University of Erlangen-Nuremberg and founded the company FMP TECHNOLOGY GMBH, whose CEO and shareholder he has been to this day.



**Dipl.-Ing. Philipp Cavadini (CN Drying Technology UG)** graduated in Aerospace Engineering at the University of Stuttgart. In his PhD studies at KIT/TFT until 2015 he investigated surface tension driven convection and the optimisation of impinging jet systems from the viewpoint of homogeneity of the distribution of the heat and mass transfer coefficient. Currently Mr. Cavadini works on cooling technologies in the department of "Methods and Technology" at Siemens Energy. In secondary employment, he is working on the spin-off creation "CN Drying Technology UG", developing highly homogeneous comb nozzle dryers for lab application.

**B. Eng. Florian Lemm (Kroenert)** completed his studies in mechanical engineering at the University of Applied Sciences in Hamburg. He joined KROENERT in 2015 and wrote his Bachelor thesis on characteristics of jet impingement heat transfer. After graduation, he started working in the Technology Center of KROENERT focusing primarily on optimization of deformable roll and other roll coating processes. In 2017 he shifted from TC to R&D department, where he is involved in development and validation of theoretical simulation tools for each process step in a typical Roll-to-Roll converting machine.

**Dr. Kai K. O. Bär (adphos)** is the Managing Director/President of the adphos Digital Printing GmbH. He was one of the founders of the IndustrieSerVis GmbH (legal predecessor of AdPhos). Before he was the leader of the business segment "High Temperature Technology and Installations" at IABG, Ottobrunn. Dr. Bär was responsible for the Technology-Program "HERMES-Heatstructure-Tests" and graduated as Dr.-Ing. (with award) at the RWTH Aachen in Germany.

**Prof. Dr. Steven Abbott (TCNF, UK)** received his Oxford PhD in Chemistry from Harvard University in 1978 and was postdoc in the Nobel Prize winning lab of Prof. J.-M. Lehn in Strasbourg before working for ICI where he was Senior Manager before joining the high-tech coating company Autotype near Oxford as Research Director. He worked closely with coating experts at U. Leeds (appointed Visiting Professor in 2000) and co-created the TopCoat and TopWeb programs for the coating industry. He now teaches, consults and troubleshoots around the world on coating, solubility, surfactant and adhesion science, using his own apps and software to bring science to life.

**Dipl.-Ing. Harald Döll (TSE, CH)** successfully graduated from the Technical University in Darmstadt in Mechanical Engineering in 1989. After some year in web-guiding systems Harald Doell joined TSE Troller AG in 1997. In the beginning, he was the head of the engineering team; since 2008, he is in charge of the entire application technology. Design of die internals, experiments with customers, start-ups and technical customer support are part of his assignment. Furthermore, he is giving talks at several short courses and international conferences in the US, in Europe and in Asia.

## Additional speakers at the 3rd TFT Forum on June 7-8

**Ir. Ike de Vries (HOLST CENTRE, NL)** studied Chemistry at the Wageningen University, Netherlands. From 1988 to 2006 Ike de Vries was a project leader and process/research engineer in the field of extrusion coating and substrate development for ink jet and photographic paper at Fuji Photo Film. Since 2006, he is a research scientist at the Holst Centre in Eindhoven, The Netherlands. He utilizes his experience to develop new (R2R) processes which enable large scale production of organic light emitting diodes (OLEDs) and photovoltaic (PV). He is a board member of the European Coating Symposium (ECS) and the International Coating Science and Technology Symposium (ISCST).

**Fritz Bircher (iPrint, CH)** studied electrical engineering at ETH Zurich. After graduating he worked as an R&D engineer for different companies developing mechatronic system solutions. In 1993 he was appointed professor at Bern University of Applied Sciences, where he started his research in inkjet printing, studying and exploring all possible jetting and dispensing principles with all kinds of materials in a wide range of applications. In 2012 he joined the University of Applied Sciences Western Switzerland in Fribourg, where he founded iPrint institute and iPrint Center for Digital Printing on the Marly Innovation Center. Fritz's main research interests based on inkjet printing include: packaging printing, direct-to-shape printing, material printing including 3D printing and bio printing.

**Prof. Dr. Tobias Kraus (Leibniz-Institut für Neue Materialien)** is a chemical engineer and materials scientist trained at TU Munich, MIT, and the University of Neuchatel. He obtained his PhD at ETH Zurich and the IBM Research Laboratory. His interests span physical chemistry, surface science, and process engineering of materials. He has been head of the Program Division "Structure Formation" since 2014 and is deputy head of the Innovation Center INM. In 2016, he became full professor for colloid and interface chemistry at Saarland University.

**Prof. Dr. Stefano Passerini (Helmholtz-Institut Ulm)** leads the Electrochemistry for Batteries group at the Karlsruhe Institute of Technology, Helmholtz-Institute Ulm, since 2014. His research activities are focused on electrochemical energy storage in batteries and supercapacitors. Co-author of more than 450 scientific papers (Scopus H-Index: 66, > 3.300 citations in 2017), a few book chapters and several international patents. He has been awarded in 2012 the Research Award of the Electrochemical Society Battery Division. Since 2015 he has been appointed as Editor-in-Chief of the Journal of Power Sources.

**Dr. Armin Modlinger (Volkswagen AG)** graduated in Chemistry at the University of Bayreuth in 2000, followed by a doctoral degree in 2004 at the Technical University Munich. After a Postdoctoral fellowship at the University of Bristol he started his career in the chemical industry at Evonik Industries in 2006, working at different positions in R&D departments associated with Lithium-Ion Technology. 2013 he became head of process technology at Litarion GmbH and later in 2017 he took over responsibility for Product and Process Development at Litarion GmbH. In April 2018 he joined the Center of Excellence Batteriezelle within the Volkswagen Group.

**Prof. Dr.-Ing. Frank Kleine Jäger (BASF SE)** is currently Senior Research Manager and Head of Solids Formulation and Handling Group at BASF SE in Ludwigshafen. In this role, he manages the global R&D activities in this field of Solids and Film Processing ranging from development of new process technologies and optimization to trouble shouting and debottlenecking in BASF's global production plants. He is Chemical Engineer with Diploma and PhD degrees from RWTH Aachen University, Germany. He also received his Habilitation from RWTH Aachen in 2004. Since 2011 he holds a Professorship as apl. Prof. Dr.-Ing. at RWTH Aachen.

**Prof. Dr. Günter Brenn (TU Graz, AT)** graduated in Aerospace Engineering from the University of Stuttgart and received his doctor's degree in 1990. He did his habilitation at the Chair of Fluid Mechanics (LSTM) of the University of Erlangen-Nuremberg (Prof. Dr. F. Durst) in 1999 and was appointed chair of the Institute of Fluid Mechanics and Heat Transfer at Graz University of Technology (A) in 2002. His research interests are capillary hydrodynamics and stability, liquid-gas two-phase flows, rheology and rheometry, heat and mass transfer, and optical flow measuring techniques.

**Milan Madron (Schaeffler AG)** finished his diploma in "Material Engineering" at the Nuremberg Institute of Technology in 2009 followed by a master's degree in "New Material, Nano and Production Technology" in 2011. Since 2011 he is working in the Competence Center Surface Technology at Schaeffler Technologies AG & Co. KG. Since 2015 he is a senior specialist and responsible for all painting and sol-gel processes at Schaeffler world-wide.

**Dr. Katerina Kampioti (CNRS Bordeaux, FR)** obtained her PhD in physical chemistry in 2016 from the University of Bordeaux. She has been working in a European (program H2020) and a French project (BPI) involving the preparation of formulations for different applications: from rubber composites to paints. She was awarded for the best oral communication during the 18th Scientific Day of the Doctoral School of Chemical Sciences in Bordeaux.

## A total of 27 speakers, including 18 external and following PhD students of the TFT group at KIT:

**Dipl.-Ing. Anna-Lena Riegel** completed her studies in Chemical Process Engineering at KIT in 2012, majoring in Thermal Process Engineering and Technical Thermodynamics. She conducted her diploma thesis as a Solvay scholarship student at the University of British Columbia in Vancouver where she investigated the formation of polymer stabilized nanoparticles for drugs applications. Further, a scholarship was granted her by the German National Academic Foundation during her studies. Since 2013 she is working as research assistant at the KIT/TFT. In her PhD she focuses on processing biosensor solutions, in particular on their special treatment during coating and drying due to sensitive components, on their sorption behavior as well as on the development of novel biosensor solutions containing conductive polymers.

**Dipl.-Ing. Ralf Diehm** graduated in Process Engineering at KIT in 2014, majoring in Thermal Process Engineering and Chemical Energy Sources. Already during his studies he started to specialize on thin film coatings of organic electronics in his student research project and of lithium-ion battery electrodes in his diploma thesis. Since 2014 he is working as research assistant at the KIT/TFT group, focussing on stability and mechanism of slot die coating and in particular of intermittent coating to provide a fundamental understanding of the process and its limitations. In 2015 he was awarded with the first price of the KIT "Neuland" award for his innovations in high speed intermittent slot die coating.

## Additional speakers and workshop instructors

Tobias Fritzensmeier (since 2015)

Jochen Eser (since 2015)

Max Tönsmann (since 2015)

Lisa Merklein (since 2016)

Jana Kumberg (since 2016)

Víctor Gracia (since 2017)

Sandro Spiegel (since 2017)

Andreas Altvater (since 2018)