

# ***Solidification Course 2022***

For the first time including a lecture on Additive  
Manufacturing with special emphasis on Rapid  
Solidification and associated defects

## **Announcement**

29<sup>th</sup> Edition

<https://www.esi-group.com/company/events/2022/solidification-course-2022>

973 participants from 355 companies from 38 countries so far!

**Les Diablerets (Switzerland)**

March 20<sup>th</sup> - 25<sup>th</sup>, 2022

## THE LECTURERS

Courses, discussions, and exercises will be presented by the following lecturers:

<i>Prof. Christoph Beckermann</i>	Professor, University of Iowa, Iowa City, USA
<i>Prof. Hervé Combeau</i>	Professor, Lorraine University, Institut Jean Lamour, Nancy, France
<i>Prof. Jon Dantzig</i>	Professor Emeritus, University of Illinois, Urbana, USA
<i>Dr Marco Gremaud</i>	Former Director of ESI Group Manufacturing Division, Lausanne, Switzerland
<i>Prof. Matthew John M. Krane</i>	Professor, Purdue University, USA
<i>Prof. Andreas Ludwig</i>	Professor, Montanuniversitaet Leoben, Austria
<i>Prof. André Phillion</i>	Associate Professor, McMaster University, Hamilton, ON, Canada
<i>Prof. Michel Rappaz</i>	Professor Emeritus, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

## SCOPE OF THE COURSE

For the twenty-ninth time, ESI Group, in collaboration with the Swiss Federal Institute of Technology of Lausanne (EPFL), is organizing a solidification course with the participation of renowned lecturers from Swiss, French, Austrian, Canadian and US universities.

This one-week course held in English is designed for engineers and scientists from industry and research centers who wish to improve their knowledge in the field of solidification. Participants should have a degree in materials science, metallurgy, mechanical engineering, chemical engineering, physics or chemistry.

Although the theoretical background of solidification is reviewed, the course is oriented towards the relation of solidification theories to industrial practice. Application of these concepts are made to processes including additive manufacturing, shape casting, continuous casting, and directional solidification in a variety of metallic systems.

The fundamental aspects of solidification (e.g., phase diagrams, heat and mass transfer) are addressed together with the formation of microstructures (e.g., grain structures, dendrites, eutectics) and defects (e.g., porosity, hot tearing, micro- and macro-segregation). Connection between macroscopic and microscopic aspects, such as the prediction of these microstructures and defects as a function of process parameters, is emphasized. For the first time in 2021, a new course covering various aspects of additive manufacturing, including rapid solidification theory, will be presented.

In addition to the lectures, group exercises, discussions, and films are organized in order to apply, practice, and visualize the course content. The interaction between the limited number of participants (maximum 40) and the eight lecturers has proven in the past to allow an optimum transfer of knowledge during the whole week, both in and out of the sessions. To continue this tradition, private or group discussions can take place during social hours, evenings, and Wednesday afternoon in order to treat more specific problems which the participants may encounter.

The course follows very closely the content of the book "Solidification" by J.A. Dantzig and M. Rappaz.

# PROGRAMME

## Sunday March 20, 2022

From 18:30 Welcome of the participants, registration  
19.15 Dinner

## Monday March 21, 2022

08.30 - 09.45 Introduction / Overview of solidification phenomena M. Gremaud  
09.45 - 10.15 Break  
10.15 - 11.15 Phase diagrams J. Dantzig  
11.15 - 12.15 Discussion/Exercises (Phase diagrams) C. Beckermann / J. Dantzig  
12.30 Lunch  
13.45 - 14.45 Heat and Mass transfer M. Krane  
14.45 - 15.45 Discussion/Exercises (Heat-Mass transfer) H. Combeau / M. Krane  
15.45 - 16.15 Break  
16.15 - 17.15 Nucleation and grain refinement in alloys A. Ludwig  
17.15 - 18.00 In-situ visualization of solidification (films) M. Rappaz  
18.30 Social Hour  
19.30 Dinner

## Tuesday March 22, 2022

08.30 - 09.30 Microsegregation C. Beckermann  
09.30 - 10.30 Discussion/Exercises (Microsegregation) A. Ludwig / C. Beckermann  
10.30 - 11.00 Break  
11.00 - 12.00 Dendritic structures J. Dantzig  
12:15 Lunch  
14.00 - 15.00 Eutectic solidification A. Ludwig  
15.00 - 16.15 Discussion/Exercises (Dendrites-Eutectic) J. Dantzig / A. Ludwig  
16.15 - 16.45 Break  
16.45 - 17.45 Mushy zone modeling H. Combeau  
18.30 "Swiss Evening" dinner

### **Wednesday March 23, 2022**

08.30 - 09.30	Porosity	C. Beckermann
09.30 - 10.30	Discussion/Exercises (Porosity)	H. Combeau / C. Beckermann
10.30 - 11.00	Break	
11.00 - 12.00	Modeling of columnar and equiaxed solidification	H. Combeau
12.15	Lunch	
	Free time (free discussions with the professors)	
18.15	Social hour	
19.15	Dinner	

### **Thursday March 24, 2022**

08.30 - 09.30	Hot tearing	A. Phillion
09.30 - 10.45	Discussion/Exercises (Hot tearing)	M. Krane / A. Phillion
10.45 - 11.15	Break	
11.15 - 12.15	Additive manufacturing: rapid solidification	M. Rappaz
12.30	Lunch	
14.15 - 15.15	Macrosegregation	M. Krane
15.15 - 16.30	Discussion/Exercises (Macrosegregation)	A. Ludwig / M. Krane
16.30 - 17.00	Break	
17.00 - 18.00	Answer to participant questions – Panel session	All
18.15	Social hour	
19.15	Dinner	

### **Friday March 25, 2022**

08.30 - 09.30	Solidification path in multi-component systems	M. Rappaz
09.30 - 10.30	Discussion/Exercises (Multi-comp)	J. Dantzig / M. Rappaz
10.30 - 11.00	Break	
11.00 - 11.45	Synthesis – Linking solidification phenomena	A. Phillion
11.45	Concluding remarks	M. Gremaud
12.00	End	
12.15	Lunch	

## PRACTICAL INFORMATION

- Dates: from Sunday March 20, 2022 evening  
to Friday March 25, 2022, mid-day (lunch included)
- Location: Hotel "Eurotel Victoria", Les Diablerets, Switzerland  
(Mountain resort in the Swiss Alps, 100 km from Geneva)  
[www.eurotel-victoria.ch](http://www.eurotel-victoria.ch)
- Access: Train or car (2.5 hours by train from Geneva Airport and  
4.5 hours by train from Zurich Airport).
- Registration: As soon as possible with the enclosed registration form  
to be sent by email to ESI Group at  
[solidification.course@esi-group.com](mailto:solidification.course@esi-group.com).

Registration is limited to 40 participants.  
All registrations will be confirmed in writing within 2-3 weeks.

- Price: EUR 4'600.- (EUR = Euro currency )  
This price includes the registration fee, the booklet of the course  
with the lecture notes, the book "Solidification", the hotel (full  
board), drinks during the meals, social hours and coffee breaks.

- Payment The course fee should be paid before February 1<sup>st</sup> 2022.  
Instruction for payment will be provided after registration.

*A confirmed registration corresponds to a firm commitment. This means that the course fee should be paid in any case, unless the registration is cancelled in writing at least 60 days prior to the start of the course.*

An information package with the practical details will be sent in advance (around mid-January 2022) to each registered participant.

*Previous courses were attended by participants from the following companies or institutions:*

**Argentina** INTI **Australia** BHP, Comalco, Uni Wollongong **Austria** AMAG, ARC, Böhler, Buntmetall Amstetten, Eisenwerk Sulzau Werfen, Giesserei Institut, Hertwich Eng., Leoben University, LKR, Mubea Wheels, Siemens, Voest-Alpine, TU Graz  
**Belgium** Allard Europe, Bekaert, Consolidated Precision Products, CRIF, Heraeus Electro-Nite Intl., KU Leuven, Magotteaux, Union Minière **Brazil** Electro Aço Altona, Gerdau, ITP, Villares Metals **Canada** Alcan, Aluminium Tech. Carlton Univ., Magotteaux, Univ. of McMaster, Univ. of Windsor, Univ. of Western Ontario **Czech Rep.** Mecas, Vitkovciv Heavy Machinery, Technical Univ. Ostrava **Denmark** Jydsk, Univ. of Denmark **Finland** Outokumpu, VTT **France** ABS Centre Métallurgique, Airbus Helicopters, Alcoa Howmet, Aperam Isbergues, Arts et Métiers Angers, Asco Metal Creas, Aubert&Duval, Cabinet Braun, Castmetal, CEA, Cemef, Cezus, Cirimat, CLAL, Clecim, Constellium, Creusot-Loire Industrie, CTIF, Ecole Centrale de Nantes, Ecole des Mines Albi, Ecole des Mines St-Etienne, Electricité de France, ENSAM, ESI Group, Fives Cryo, Fonderie Nouvelle Jouve, Forcast, Griset, Howmet, Imphy, Industeel, INPG, INPT, Institut Jean Lamour, IRSN, Le Bélier, Manoir Industries, Manoir St Brieu, Metafensch, Montupet, Péchiney, Pont-à-Mousson, Renault, Rio Tinto Alcan, Safran, Saint-Gobain Cree, Sambre et Meuse, SCC, Sepr, Safran, Snecma, Techpy, Trefimetaux, Turbine Casting, ThyssenKruppElectrical Steel, Ugine, Ugitech, Umicore, Unimetal, Univ. de Lorraine, Vallourec, Waeles, Wamar **Germany** Access, Airbus, Aleris, Aluminiumfeinguss Soest, Aurubis, Buderus Edelstahl, Daimler Chrysler, DLR, Doncasters, Fraunhofer, GKSS, Helmholtz Zentrum, Hydro, MAN, MKM, MTU, Otto Fuchs, Ritter AI, Salzgitter Mannesmann, Reiner Brach, Siempelkamp, Schmidt & Clemens, SMS Diemag, SMS Group, Thyssen, Tital, TU Dresden, TU Freiberg, VAW, Zollern **Greece** Alcor, Egnatia foundry, Elkeme, Elval **India** Anant, Concast, ESI India, GM, HAL, Jadavpur University, Kalyani Carpenter, Peekay Steel, Simplex Castings, Sri Ranganathar Valves **Ireland** DePuy, Dublin Inst. Of Tech., Materials Ireland, Montupet **Israel** NRCN, Urdan **Italy** Area3, Brembo, Centro Ricerche FAR, Fiat, Centro Sviluppo Materiali, Danieli, ECOTRE, EMA, Europa Microfusioni Aerospaziali, Fonderia Atti, Metra, Microfusione Stellite, Politecnico di Torino, Refel, Teksid, Univ. of Bologna, Univ. of Brescia, Zanardi Fonderie **Japan** IHI, JIPS, Kyushu University, Mitsubishi Heavy Industries, Nihon ESI, Nippon Steel, Tokyo University **Korea** Hyundai Heavy Ind., Inst. Ind. Tech.  
**Mexico** Castech, Cinfusa, Ciateq **Netherlands** Bosch, Corus, ESA, Honeywell, Hoogovens, MI2, NIMR, Outokumpu, Shell, Tata Steel, TU Delft, Univ. of Groningen **New Zealand** AW Frazer, Supreme Steel Precision **Norway** Elkem, Elkem Solar, Elkem Silicon Materials, Hycast, Hydro, IFE, NTNU, K.A. Rasmussen, Sintef **Poland** AGH, CPP, GE Polska, Rzeszow Univ. of Tech., Warsaw University, WSK **Portugal** Funfrap, Instituto Superior Tecnico, Zollern **Russia** Aviadvigatel OJSC, FSUE MMPP SALUT, KUMW, Perm National Research **Saudi Arabia** King Saud University, Sabic **Slovak Rep.** US Steel **Slovenia** Impol D.D., IMT, Talum D.D., TGC Unitech, Univ. of Nova Gorica **South Africa** Mattek-CSIR, Scaw Metals **Spain** Analisis y Simulación, C4, Centro Metalurgico Azterlan, Cidaut, CTM, Edertek, Fagor Ederlan, Fuchosa, Inasmet, Labein, Mondragon Univ., Precicast, Sidenor, Univ. Vigo **Sweden** ABB, Erasteel Kloster, Gränges Technology, KTH, Lulea University, MEFOS, Ovako Steel, Sandwik Rock, SAPA, Swedish Foundry Ass., Swerea Swecast, Swerim, Volvo Truck, Volvo Powertrain, TPC **Switzerland** Advanced Aerofoil Technologies, Alcan, Algroup, Argor-Heraeus, Asulab, Bühler, Cendres et Métaux, Concast, FHNW, HES SO, Kugler Bimetal, Metalor, Nivarox, Novelis, Nussbaum, Precicast, PSI, PX Holding, Rolex, SMS Concast, Steel Consult, Sulzer, Swatch Group, Swissmetal, Swiss Steel, UMS, Unitechnologies, Varinor, Wolfensberger **Taiwan** Nat. Taiwan Uni. **Thailand** INN, Somboon **Turkey** Assan Kibar Group, CMS, Eregli, Eyap Artema, FNSS Defense Systems, Gedik Döküm **United Arab Emirates** Dubai Aluminium, Gulf Extrusions, Masdar Institute **United Kingdom** AETC, Aeromet International, Alloy Wheels, Ashland, AWE, British Aerospace, Doncasters, GKN, Namtec, Rolls Royce, Sheffield Forgemasters, Sim-Cast, T&N Technology, Trittech Group, Univ. of Birmingham, Univ. of Cambridge, Univ. of Cranfield, Univ. of Leicester, Univ. of Sheffield, Univ. of Swansea, Vulcan, Wall Colmonoy **USA** Alumax, Carnegie Mellon, Carpenter Technology, Caterpillar, CNS, Consolidated Metco, Dura-Bar, Ellwood Quality Steels, ESI R&D, Ford Motor Company, General Electric, GM, Hitchiner Manufacturing, Hoeganaes, Honeywell Aerospace, Howmet, Los Alamos Natl. Lab., Magotteaux, Naval Surface Center, NIST, Novelis, PCC Structural, Pratt & Whitney, Purdue University, Signicast Investment, Stuller, United Technologies, Univ. of Binghamton, Univ. of Illinois, Univ. of Iowa, Univ. of Ohio, Virginia Tech, Wagstaff, West Coast Foundry, Wright Patterson AFB, Wyman Gordan