Time Table (CET, Rome, Paris, Prague)

	Feb. 6 Sunday		Feb. 7 Monday	Feb. 8 Tuesday	Feb. 9 Wednesday	Feb. 10 Thursday
		9.00 – 10.00	**1st lecture** (IPM & online) Prof. Liviu Marsavina *Presentation of the SIRAMM project*	**5th lecture** (online) Prof. Donato Firrao Prof. Filippo Berto Prof. Francesco Iacoviello *"Additive manufacturing in metals and defects: a challenging topic"*	**10th lecture** (online) Prof. Javad Razavi *"Fatigue life extension by crack repair"*	**12th lecture** (IPM & online) Prof. Roxana Ghita *"Gender (im)balance in science and engineering – a cross-cultural perspective"*
		10.00– 11.00	**2nd lecture** (online) Prof. Snezana Kirin *"Statistical methods for evaluating the experimental data obtained by testing AMM"*	**6th lecture** (online) Dr. Marco Maurizi *"Data-driven approaches for modeling and design of additive manufactured architected materials"*	**11th lecture** (IPM & online) Dr. Jan Cizek *"Cold spray Additive Manufacturing"*	**13th lecture** (IPM & online) Prof. Marian Janek *"Additive manufacturing of bioactive personalised hard tissue replacements"* Prof. Lubos Baca, *"Opportunities and challenges in the fused deposition modeling of ceramics"*
		11.00 – 11.30	Break (IPM)	Break (IPM)	Break (IPM)	Break (IPM)
		11.30 – 12.30	**3rd lecture** (IPM & online) Dr. Jaroslav Kovacik *"Cross-properties in Cu-graphite composites and aluminium foams and their applicability to Additive Manufacturing of materials"*	**7th lecture** (online) Prof. Florian Arbeiter *"Mechanical properties of layered polymers produced via extrusion-based additive manufacturing"*	**Practical session 1** (IPM & online) Advanced testing	**Final exam** (IPM & online)
		12.30 – 14.30	Lunch	Lunch	Lunch	Lunch
14.30 – 16.30 16.30 – 17.00	Welcome reception & registration (IPM) Opening of the winter School (IPM & online):	14.30 – 16.00	**4th lecture** (online) Dr. Francesco Puzello *"Additive Manufacturing from prototype to mass customization: a new industrial revolution. Challenges in AM production"*	**8th lecture** (online) Dr. S. Tavernini (*) *"The Marie Sklodowska-Curie Actions in Horizon Europe, with a special focus on postdoctoral fellowship"*	**Practical session 2** (IPM & online) *Brno Univ. of Tech.* *3D printers for metals*	14.30 – 15.30 **Discussion session** (IPM & online) Research, future perspectives and international collaborations on AM in engineering
		16.00 – 17.00	**Presentation of some participants' backgrounds and current activities** (IPM & online)	**9th lecture** (online) Prof. Chao Gao *"Structural Integrity of Additive Manufactured Components – Introduction to AM of polymer component"*	(*)16.00 – 17.00 (IPM & online) Dr. S. Tavernini will be available to discuss and answer questions by the winter school attendee on research funding and related tips	15.30 – 16.00 **Closing of the winter School** (IPM & online)

SIRAMM

H2020-WIDESPREAD-2018, Grant No. 857124

2nd Winter School on

Trends on Additive Manufacturing for Engineering Applications

Institute of Physics of Materials (IPM)

Brno, Czech Republic, 6th-10th February 2022

in presence & online

Winter school info

The 2nd winter school on **Trends on Additive Manufacturing for Engineering Applications** will be held in Brno, 6-10 February 2022. The main aim of the Winter School is to involve PhDs and young researchers in the field of AM with an engineering perspective. The winter school is an annual key activity of the European Twinning Project **SIRAMM**, funded by the European Union's Horizon 2020, H2020-WIDESPREAD-2018-03 under the grant agreement No. 857124.

The winter school will consider both scientific aspects concerning Additive Manufacturing as well as soft skills in research such as scientific and grant proposal writing, gender aspects, etc. Practical sessions concerning designing, manufacturing and testing of 3D-printed objects will be organized.

Venue

The winter school will be held at the

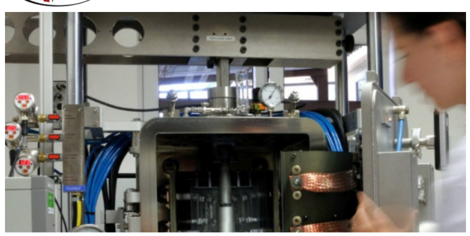
Institute of Physics of Materials

(Czech Academy of Sciences, IPM),

Zizkova 513/22, 616 00 Brno, Czech Rep. & Online

http://www.siramm.unipr.it/Events.htm

Institute of Physics of Materials
Czech Academy of Sciences



Winter school Fees

Participation in the winter school is free!

Lunches and coffee breaks will be included

A limited number of places is available (max. 30)

The selection process for participating to the winter school will be based on the participant's country, with a preference for east European countries. Participation of PhDs, post-docs and young researchers as well as women will be especially preferred. Gender equality and equal opportunities will be key-aspects in the selection of the participants.

Prospective Key Dates

Registration:	31st January 2022
Confirmation to participants:	3rd February 2022

Lectures

All lectures will be given in English.

Speakers

Prof. Liviu Marsavina, UPT Timisoara, Romania
Prof. Snezana Kirin, Univ. of Belgrade, Serbia
Dr. Jaroslav Kovacik, Institute of Materials and Machine Mech., Slovak Academy of Sciences SAS, Slovakia
Dr. Francesco Puzello, BI-REX - Big Data Innovation & Res. Excellence, Italy
Prof. Donato Firrao, Polytechnic Univ. of Turin, Italy
Dr. Marco Maurizi, NTNU Trondheim, Norway
Prof. Florian Arbeiter, Montanuniversitaet Leoben, Austria
Dr. Silvia Tavernini, Univ. of Parma, Italy
Prof. Chao Gao, NTNU Trondheim, Norway
Prof. Javad Razavi, NTNU Trondheim, Norway
Dr. Jan Cizek, Czech Academy of Sciences, Prague, Czech Rep.
Dr. Roxana Ghita, UPT Timisoara, Romania
Prof. Marian Janek, Slovak University of Technology, Slovakia
Dr. Lubos Baca, Slovak University of Technology**,** Slovakia

Accommodation

In Brno there are plenty of possibilities for accommodation.
Please refer to this website for more info about accommodation for students. Other possibilities:
Sono Hotel
Hotel University Brno
A-Sport Hotel

Registration (Winter School Office)

For registration please send an email either to:

- Dr. Michal Zouhar: zouhar@ipm.cz
- Prof. Roberto Brighenti: brigh@unipr.it
- SIRAMM staff: SIRAMM.Twin@gmail.com

or fill the online form

ECTS credits

3 ECTS will be recognized for the participation (for at least 70% of the lectures) to the winter school. **2 more ECTS** will be recognized upon the positive evaluation of the final assessment test.

Lectures details

1st lecture – **Prof. Liviu Marsavina**

University Politehnica Timișoara, Romania

Presentation of the SIRAMM project

This lecture presents the main activities and goals of the H2020 SIRAMM project and the future perspectives related to the structural integrity and reliability of materials obtained through additive manufacturing.

2nd lecture – **Prof. Snezana Kirin**

Univ. of Belgrade, Serbia

Statistical methods for evaluating the experimental data obtained by testing AMM

The lecture will cover the methods used today to process and interpret data obtained by testing additive manufacturing materials (AMM) in order to describe and evaluate their properties. Methods of descriptive statistics will be presented in aim to summarize obtained observations, to estimate their reliability, to make comparisons, and to draw inferences (measures of central tendency such as the mean, median, and mode summarize the performance level of a group of scores, and measures of variability describe the spread of scores among experimental samples). In the following, the transition from sample description to population inference through inferential statistical methods will be presented throw: The Role of Probability Theory, The Null and Alternative Hypothesis, The Sampling Distribution and Statistical Decision Making, Type I Errors, Type II Errors, Statistical Power and Effect Size. Parametric and non-parametric group comparison tests, ANOVA and Kruskal Wallis test will be presented through examples. It will also be shown how the software (MS EXCEL and IBM SPSS) can be used to process the obtained data.

3rd lecture – **Dr. Jaroslav Kovacik**

Institute of Materials and Machine Mechanics, Slovak Academy of Sciences SAS, Slovakia

Cross-properties in Cu-graphite composites and aluminium foams and their applicability to Additive Manufacturing of materials

Copper–graphite composites (in the range of 0–50 vol% of graphite) were prepared from the mixture of copper and graphite powder by the powder metallurgy method – hot isostatic pressing.

The microstructure and physical properties (density, electrical and thermal conductivity, thermal expansion coefficient) were measured and compared with predictions. Explicit cross-property connections between pairs of different physical properties were established and compared with the experimental data. The cross-property connection that express were derived, in the closed form, the effective thermal expansion coefficients and the thermal conductivities of anisotropic composites in terms of effective electrical conductivity. These cross-property connections are important for applications since overall thermal and electrical properties of composites are not independent from each other but are interrelated through microstructural parameters. It becomes especially important, when two or three different physical properties have to be optimized at the same time.

Further, the elastic shear modulus and electrical conductivity were measured and normalized dependences of these quantities on volume fraction of graphite have been compared. The explicit cross-property connections between these two physical properties were established and the results were compared with the theoretical predictions for particles having perfect spheroidal shape. The difference is mild that confirms hypotheses of Bristow (1960) that shape irregularities of the inhomogeneities affect linear elastic and conductive properties of heterogeneous materials in similar way. These cross-property connections are important for applications since overall elastic and electrical properties of composites are not independent from each other. They are interrelated via microstructural parameters - mostly shape and volume concentration of the inhomogeneities. This interrelation becomes especially important, when both of these properties have to be optimized simultaneously (as in the most applications where copper-graphite composites are used).

Foamed aluminium (AlMg1Si0.6) in the porosity range 0.45–0.85 produced by the powder metallurgy route was analysed with regard to its elastic and electric properties. Young's modulus and electrical conductivity of closed cell foamed aluminium exhibit a marked similarity in dependence on the pores volume fraction. The differential scheme provides the best predictions of the electrical conductivity and also for the Young's modulus. Comparing the two sets of the experimental data, cross-property coefficient that connects changes in the Young's modulus and electrical conductivity of a material due to pores was determined. A non-trivial finding is that the best prediction of the cross-property coefficient is obtained in the framework of non-interaction approximation. It is important as non-interaction approximation gives qualitatively incorrect prediction for both elastic and conductive properties of the foams. This fact is quite nontrivial: it means that the effects of the pore shape and pores interaction affect both elastic and conductive properties in similar manner. Therefore, the cross-property coefficient for closed-cell aluminium foam may be well described by simple formula which neglects pore shapes (all the pores are considered as spherical) and pore interactions.

4th lecture – **Dr. Francesco Puzello**

BI-REX - Big Data Innovation & Research Excellence, Italy

Additive Manufacturing from prototype to mass customization: a new industrial revolution. Challenges in AM production

Additive manufacturing technologies represent a tool through which industry is rewriting the paradigms of production worldwide. From the early 1980s to today, prototyping machines have become real production systems able to develop new applications with ever-increasing levels of performance. The global manufacturing industry is experiencing a transition phase through which production becomes custom on-demand. Technologies, processes, and design for additive manufacturing are outlining the future economic and social scenarios of a new industrial revolution.

5th lecture – **Prof. Donato Firrao[1], Prof. F. Berto[2], Prof. F. Iacoviello[3]**

[1] Polytechnic Univ. of Turin, Italy

[2] NTNU, Norway

[3] Univ. of Cassino, Italy

Additive manufacturing in metals and defects: a challenging topic

Being Additive Manufacturing (AM) a relatively recent manufacturing process, there are not several defect compilations, nor in depth descriptions of defect healing methods. Yet, structural integrity is important in AM fabricated components and can be reached by proper knowledge of AM procedures and of Post Processing Treatments. A thorough description of defects in various metal alloys used to obtain high values of UTS, or complex light structures, or temperature or corrosion resistance, will be given. Illustration of results of various defect-reducing methods as HIP, Selective Laser Melting, and Electron Beam Melting will lead to a comparison of resulting quasi- static mechanical properties and fatigue resistances.

6th lecture – **Dr. Marco Maurizi**, NTNU Trondheim, Norway

Data-driven approaches for modeling and design of additive manufactured architected materials

The great advances of additive manufacturing have in the recent years allowed to design and fabricate materials with complex structures from nano- to macro-scale. Architecting the structure of materials rather than their composition has shown to be a promising design approach. At the same time, the rapid growth of data-driven approaches, especially machine learning, has provided powerful tools to design and discover novel advanced materials with unique properties, including high stiffness-to-weight ratio, simultaneous high strength and toughness, and tailorable stiffness anisotropy. This lecture is aimed to provide some general knowledge on data-driven methods, with focus on deep-learning, architected materials, and recent developments on machine-learning-based design of architected materials, such as hierarchical composites, interlocking and lattice structures, and spinodoid metamaterials.

7th lecture – **Prof. Florian Arbeiter**, Montanuniversitaet Leoben, Austria

Mechanical properties of layered polymers produced via extrusion based additive manufacturing

With the rise of the topics of additive manufacturing, layered polymers have become a topic of interest as of late. In additive manufacturing the design of freedom is usually the primary target and the layered structure is mainly a side-effect of the processing itself. However, it can also be used to specifically tailor mechanical properties. In order to do so, it is necessary to understand the mechanics of a layered polymer in its entirety. This entails profound understanding of the influence of the processing induced weld-lines, including effects such as interlayer diffusion, diss- and entanglement, as well as morphological features due to the complex thermal history. Depending on the exact processing history and chosen material, it is shown that it is possible to produce either highly anisotropic, but also close to isotropic material behaviour. Based on differences in the weld-strength between individual layers, cracks were shown to either propagate across different layers, lead to delamination between layers or produce a mixture of both. While delamination between layers leads to a significant decrease in elastic properties, it also can vastly increase the toughness of a layered structure. Since the exact strength of an interlayer is hard to control, the implementation of a soft interlayer can alternatively be used to reach a similar effect.

8th lecture – **Dr. Silvia Tavernini**, Univ. of Parma, Italy

The Marie Skłodowska-Curie Actions in Horizon Europe, with a special focus on postdoctoral fellowships

The Marie Skłodowska-Curie Actions (MSCA) are the European Union's reference programme for doctoral education and postdoctoral training. They contribute to excellent research, boosting jobs, growth and investment by equipping researchers with new knowledge and skills through mobility across borders and exposure to different sectors and disciplines.

Among MSCA, the postdoctoral fellowships support researchers with a PhD and not more than 8 years of research experience, regardless of age and nationality. Researchers working across all disciplines are eligible for funding. The grants cover the remuneration costs for the researchers (with an allowance for researchers with family), and the costs for training, research and networking.

During the seminar, the different opportunities offered by the MSCA will be presented with a special focus on MSCA PF fellowship. The characteristics of the call, the proposal template and the evaluation criteria will be examined

9th lecture – **Prof. Chao Gao,** NTNU Trondheim, Norway

Structural Integrity of Additive Manufactured Components – Introduction to AM of polymer components

Additive manufacturing (AM) has gradually transformed industries and made work easier for scientists and engineers. Recent advances in AM of polymer components not only enable scientists develop novel materials with unusual mechanical properties, but also allow engineers fabricating load-bearing components instead of prototypes. Moreover, the cost of AM of polymer components is relatively low, leading to vast applications in industries such as marine, aerospace, and medicine.

This lecture provides learners with a fundamental understanding of AM of polymer components, especially for the fused deposition modeling (FDM) and Polyjet technology. The lecture includes:

1. Working principles of AM of polymer components. (i) Liquid polymer systems (Stereolithography process and Polyjet process); (ii) Molten material systems (FDM process).
2. Material properties and testing methods of 3D printed polymer components.
3. Mechanics of 3D printed polymer components.
4. Design principles and performance of 3D printed advanced materials.

Lecture outline:

Part 1

1. Introduction to AM of polymer components
2. Challenges to understand mechanical properties of 3D printed polymer parts.

Part 2

1. Case study: Mechanics of polymer fused deposition modeling (FDM) parts.
2. Case study: Bioinspired architectured materials

10th lecture – **Prof. Javad Razavi,** NTNU Trondheim, Norway

Fatigue life extension by crack repair

Cracks are very often generated in structural elements during their service lives. Cracks can also be created during the manufacturing process of the component or structure. Welding, casting and machining are technological processes that may produce cracks and other defects. Under cyclic loading, the crack may extend until final failure in the cracked element. Hence, it is very useful to arrest the crack growth by appropriate methods before catastrophic failure. The aim of such methods is to extend the fatigue life of cracked structural components that cannot be replaced as soon as the crack is observed; this situation commonly happens when the replacement of new parts is time consuming and costly. Various methods proposed by researchers for crack growth retardation will be reviewed in this talk and a numerical tool for evaluating the efficiency of stop drill hole as a crack arresting technique will be evaluated.

11th lecture – **Prof. Jan Cizek,** Czech Academy of Sciences, Prague, Czech Rep.

Cold spray Additive Manufacturing

Additive manufacturing (AM) is a progressive approach to production of engineering components. The method represents a unique solution, where, unlike traditional methods, the production takes place layer by layer; consequently, it is not necessary to remove excessive material by machining to achieve the final shape. The emergence of AM processes in the Industrial revolution IV will result in a sustainable production, combining benefits such as energy savings and reduced use of expensive or difficult-to-obtain materials.
Conventional, laser-based AM technologies operate based on thermal energy (melting and re-solidification of a given material) and are limited by relatively low deposition rates and often limited component dimensions. In addition, the melting of the material carries the risk of undesired changes in the material, such as oxidation, tensile residual stresses, phase changes or recrystallization.
Cold spray is a completely new, advanced method of component production in the form of additive production. Its fundamental principle is acceleration of powder particles to supersonic speeds and their subsequent deformation and connection and joining upon impact with the substrate. It is more environmentally friendly than other AM technologies and its low-temperature character, scalability, and overall simplicity of production completely eliminate the above-mentioned detrimental effects. Compared to laser methods, it enables more than ten times faster production, offers the ability to operate with materials sensitive to elevated temperatures or contact with air, and has virtually no limits on the size of components or the production of components from multiple metals and alloys.

12th lecture – **Prof. Roxana Ghita**, University Politehnica Timișoara, Romania

Gender (im)balance in science and engineering – a cross cultural perspective

The aim of this interactive lecture is to explore gender gaps leading to a career in science and engineering, from the decision to enrol in a degree, to the scientific fields that both genders pursue and the sectors in which they work. Moreover, the lecture sets out to outline the combination of factors which leads to the emergence of this gender imbalance at each stage of a scientific career: the graduate-level environment, performance evaluation criteria, the lack of recognition, lack of support for leadership skills development and conscious or

unconscious gender bias.
The lecture focuses on both a national, as well as a trans-national and cross-cultural perspective of gender imbalance in science and engineering. Participants are encouraged to bring their own input on this topic, based on both their personal and cultural experience, as there are regions that encounter even more barriers as a result of cultural norms that discourage women from taking traditionally male roles, thus generating an even greater gender imbalance.
The final part of the interactive lecture aims to discuss policies for gender equality that have already been created and their efficacy, as well as other approaches that can be taken in order to ensure an equitable and diverse work environment in science and engineering.

13th lecture – **Prof. Marian Janek, Prof. Lubos Baca**

Slovak University of Technology, Slovakia

Part 1 (Prof. Marian Janek)

Additive manufacturing of bioactive personalised hard tissue replacements

Additive manufacturing (AM) technologies have created great breakthroughs in multidisciplinary sciences including biological and medical sciences related to hard tissue engineering approaches. All material applications must challenge the features demanding by the natural biomimicking the soft and hard tissue interaction. One of the potent forming technologies include melted material extrusion of ceramic composites using techniques known also as FDM, FFF or FDC. In addition, various concepts for production of applicable scaffolds can be found in the literature: i) scaffolds based on pure biocompatible polymers such as PLA (Polylactic acid) or high performance polymer PEEK (Polyether ether ketone) ii) composite scaffolds with biocompatible inorganic phase such as Hydroxyapatite (HAp), calcium phosphates (CaP) or biocompatible glass (BCG) iii) production of HAp ceramic scaffolds after debinding of polymeric matrix and HAp sintering at elevated temperature to desired density. Successful production of HAp scaffolds was done on DIM SUT, while sintering of HAp resulted in enhanced biocompatibility during in vitro test of cytotoxicity.

Part 2 (Prof. Lubos Baca)

Opportunities and challenges in the fused deposition modeling of ceramics

Additive manufacturing (AM) technologies cover wide range of processes for the production of a physical objects created directly from a computer-aided design (CAD) model using layer-by-layer deposition. Fused deposition modeling (FDM) is one of the AM processes in which a thermoplastic filament is extruded through a nozzle and deposited in semiliquid state in the form of roads to fill each layer of the 3D part on to a platform. Depending on the feedstock materials this low-cost technology can be widely used not only for hobby purposes but also for structural and high-tech applications. This presentation provides a more insight into the world of ceramic based filaments, their development, production and finally printing of 3D complex shaped objects. A special attention will be paid to binder removal and sintering of printed parts. Finally, constrains and challenges of this technology will be reviewed.