

TIME TABLE

TIME	Monday September 27	Tuesday September 28	Wednesday September 29	Thursday September 30	Friday October 1
09.00 - 09.45	Registration	Kamal	Kamal	Vella	Vella
09.45 - 10.30	Botto	Kamal	Botto	Vella	Dai
11.00 - 11.45	Pugno	Kamal	Joly	Dai	Dai
11.45 - 12.30	Pugno	Kamal	Joly	Dai	Open panel discussion
14.00 - 14.45	Pugno	Botto	Joly	Vella	
14.45 - 15.30	Participants preentations	Botto	Joly	Vella	
16.00 - 16.45	Participants preentations	Botto	Joly	Dai	
16.45 - 17.30	Guest lecture	Guest lecture	Guest lecture	Guest lecture	
18.00	Welcome aperitif				

ADMISSION AND ACCOMMODATION

The course is offered in a hybrid format, allowing participants the flexibility to attend either in person or remotely via the Microsoft Teams platform. Admission to on-site attendance is granted on a first-come, first-served basis to comply with the capacity of the lecture room.

Registration fees:

- **Early Bird On-Site Participation: € 650.00 + VAT***

Deadline: July 27, 2027

- **Late On-Site Participation: € 800.00 + VAT***

Deadline: September 15, 2027

- **Live Streaming Online Participation: € 250.00 + VAT***

Deadline: September 15, 2027

On-site participation includes a complimentary bag, five fixed menu buffet lunches, hot beverages, downloadable lecture notes.

Online participation includes downloadable lecture notes.

Application forms should be submitted online through the website: <http://www.cism.it>. A confirmation message will be sent to participants whose applications are accepted.

Upon request, and subject to availability, a limited number of on-site participants can be accommodated at the CISM Guest House for € 35 per person per night. To request accommodation, please contact: foresteria@cism.it

* where applicable; bank charges are not included - Italian VAT is 22%.

CANCELLATION POLICY

Applicants may cancel their registration and receive a full refund by notifying the CISM Secretariat in writing (via email) no later than:

- July 27, 2027, for early bird on-site participation;
- August 27, 2027, for late on-site participation;
- September 15, 2027, for online participation.

No refunds after the deadlines. Cancellation requests received before these deadlines and incorrect payments will be subject to a € 50.00 handling fee.

CISM GRANTS

A limited number of participants from universities and research centers who do not receive support from their institutions can request a waiver of the registration fee and/or free lodging.

Requests must be submitted via the CISM website by **July 27, 2027**. Applicants should select the relevant option in the online application form and provide a curriculum vitae and a letter of recommendation from their department head or supervisor confirming that their institution is unable to provide financial support. Preference will be given to applicants from countries that sponsor CISM.

For further information please contact:

CISM (Seat of the course)
Palazzo del Torso - Piazza Garibaldi 18 - 33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
e-mail: info@cism.it | www.cism.it



MECHANICS FOR ULTRATHIN 2D MATERIALS: FLUID-STRUCTURE INTERACTIONS, CAPILLARITY AND DEFORMATION

CISM Advanced School
coordinated by

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University of Trento, Italy

Udine September 27 - October 1 2027

MECHANICS FOR ULTRATHIN 2D MATERIALS: FLUID-STRUCTURE INTERACTIONS, CAPILLARITY AND DEFORMATION

The discovery of graphene and the growing family of crystalline, atomically thin two-dimensional (2D) materials has generated enormous interest across physics, chemistry and engineering. As research has moved from understanding fundamental properties toward technological applications, the production and integration of 2D materials requires the application of rational principles of solid and fluid mechanics to predict and control manufacturing processes and prevent defects. This course provides the necessary knowledge to understand the field of 2D materials from the point of view of mechanics, focusing particularly on the main theoretical principles that have been established recently in the area of fluid-solid coupling. These include, in addition to results on nanomechanics in

“dry” environments, fluid-solid interactions in 2D particulate suspensions, flow-induced fracture of 2D materials in turbulent and laminar flows, as well as capillarity and adhesion phenomena during wet and dry transfer.

Target audience: the course is designed for two overlapping classes of researchers. On the one hand, PhD students and early-career researchers working on 2D materials. On the other hand, researchers at any career stage with a background in mechanics (e.g. non-linear and fracture mechanics of thin sheets, multiphase flows with slender bodies/particles/cells, and fluid-structure interaction phenomena) wishing to enter the rich field of 2D materials research. It also provides an entry point for condensed-matter physicists interested in connecting atomistic phenomena

with mesoscopic mechanics. Knowledge of 2D materials research is not assumed.

Course format: The course will bridge theory and applications, both during the lectures and via **online “guest lectures” with leaders of academic or industrial research centers working on technological translation of 2D materials**. Each lecturer will first provide the students foundational knowledge (elements of fracture mechanics, thin-plate mechanics, suspension hydrodynamics, interfacial physics) before providing examples of applications of such knowledge to specific industrial or academic problems. During the course, students will be given the opportunity to present their own research via dedicated poster and presentation sessions, and discuss their research lines with the lecturers in order to spur

new research collaborations.

Benefits of attending the course: Overall, the course aims to establish the emerging field of mechanics of 2D material processing by bridging fundamental mechanics, nanotechnology and manufacturing. The scientific community interested in 2D materials is one of the largest in the world, and there is a need for experts in solid and fluid mechanics to contribute to many production and characterisation challenges. The course offers a point of entry to the 2D materials revolution that is currently defining the future of microelectronics (2D chips, 2D photonics) and countless other technologies. Furthermore, the course offers very useful foundational knowledge that can be of interest to anybody working on the fluid or solid mechanics of thin structures.

PRELIMINARY SUGGESTED READINGS

Pugno, N. M., & Ruoff, R. S. (2004). Quantized fracture mechanics. *Phil. Magazine*, 84(27), 2829-2845.

Pugno, N. M. (2006). Dynamic quantized fracture mechanics. *Int. J. of Fracture*, 140(1), 159-168.

Guazzelli, E., & Morris, J. F. (2011). *A physical introduction to suspension dynamics*. Cambridge University Press.

Kamal, C., Gravelle, S., & Botto, L. (2021). Effect of hydrodynamic slip on the rotational dynamics of a thin Brownian platelet in shear

flow. *J. Fluid Mechanics*, 919, A1.

Yi, M., & Shen, Z. (2016). Fluid dynamics: an emerging route for the scalable production of graphene in the last five years. *Rsc Advances*, 6(76), 72525-72536.

Salussolia, G., Barbieri, E., Pugno, N. M., & Botto, L. (2020). Micromechanics of liquid-phase exfoliation of a layered 2D material: A hydrodynamic peeling model. *J. Mech. Phys. Solids*, 134, 103764.

Lee, C., Wei, X., Kysar, J. W., Hone, J. (2008). Measurement of

the elastic properties of graphene and intrinsic strength of monolayer graphene, *Science*, 321, 385.

Duprat, C. and Stone, H. A. (2015). “Fluid-structure interactions in low Reynolds number flows”. *R. Soc. Chem. Soft Matter Series*.

Sun, Y. W. et al. (2021), Mechanical properties of graphene, *Appl. Phys. Rev.* 8, 021310.

Akinwande et al. (2017). A review on mechanics and mechanical properties of 2D materials—

Graphene and beyond. Extreme Mechanics Lett., 13, 42-77.

Israelachvili, J. N. (2011). *Intermolecular and surface forces*. Academic press.

Bocquet, L., Charlaix, E. (2010). Nanofluidics, from bulk to interfaces. *Chem. Soc. Rev.*, 39, 1073.

Gravelle, S., Alvares, C. M. S., Gissinger, J. R., & Kohlmeyer, A. (2025). A Set of Tutorials for the LAMMPS Simulation Package *Living Journal of Computational Molecular Science*, 6(1), 3027.

INVITED LECTURERS

Lorenzo Botto - Delft University of Technology, the Netherlands
5 lectures on: liquid-phase exfoliation of layered particles in laminar and turbulent flows, particularly focusing on the modelling of hydrodynamic forces and flow-induced fracture phenomena; an introduction to capillary trapping of 2D material at fluid interfaces

Zhaohu Dai - Peking University, China
5 lectures on: nanoindentation and mechanical characterization of 2D materials; interfacial mechanics; transfer, assembly, and cleaning of 2D materials; thin films, bubbles, blisters; strain engineering for multifunctional devices and emerging applications.

Catherine Kamal - University College London, United Kingdom
5 lectures on: an introduction to the theory of suspension hydrodynamics, continuum based modeling approaches for fluid-structure interaction of ultrathin particles including slender body theory and the boundary integral formulation, and 2D ink rheology and its application.

Laurent Joly - Université Lyon 1, Villeurbanne, France
5 lectures on: molecular modeling of liquid-solid interfaces in 2D materials (general principles, and implementation with LAMMPS code): nanoscale hydrodynamic boundary condition (liquid-solid slip and friction), adhesion and capillarity (work of adhesion, surface tension), limits of continuum hydrodynamics, coupled transport (osmotic flows, electrokinetic effects).

Nicola M. Pugno - University of Trento, Italy
3 lectures on: an introduction to linear elastic and quantized fracture mechanics and its application to 2D materials, including characterization and constitutive laws for the materials strength, toughness, cracks and defects; dynamic quantized fracture mechanics.

Dominic Vella - University of Oxford, United Kingdom
5 lectures on: Models for thin elastic sheets (Föppl-von Kármán equations); distinction between bending and stretching and its consequences; indentation measurements; static and dynamic buckling; wrinkling; effective properties of wrinkled sheets; capillary effects on ultrathin sheets; hydrodynamically-controlled deformation.

Guest lectures: the course will include online interactive “guest lectures” (with Q&A components), with industrial and academic leaders in technological translation of 2D materials. Invited speakers include F. Bonaccorso (BeDimensional Spa and Istituto Italiano di Tecnologia, IT), R. Adelung (Kiel University, DE), E. Bonaccorso (Airbus Central R&T, DE) and representatives of Graphenea Semiconductor SL (ES).

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.