## TIME TABLE

**(Registration on Monday at 8:30)**

| TIME | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|
| | July 18 | July 19 | July 20 | July 21 | July 22 |
| 9.00 - 9.45 | Kroto | Gao | Buehler | Persson | Pugno |
| 9.45 - 10.30 | Kroto | Gao | Buehler | Persson | Pugno |
| 11.00 - 11.45 | Ruoff | Ruoff | Gorb | Gorb | Pugno |
| 11.45 - 12.30 | Ruoff | Ruoff | Gorb | Gorb | Pugno |
| 14.30 - 15.15 | Gao | Gao | Buehler | Persson | |
| 15.15 - 16.00 | Gao | Gao | Buehler | Persson | |
| 16.30 - 17.15 | Ruoff | Buehler | Persson | Gorb | |
| 17.15 - 18.00 | Ruoff | Buehler | Persson | Gorb | |

## ADMISSION AND ACCOMMODATION

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through our web site: http://www.cism.it or by post.

A message of confirmation will be sent to accepted participants. If you need assistance for registration please contact our secretariat.

The 700,00 Euro registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday not included), hot beverages, on-line/downloadable lecture notes and wi-fi internet access.

A limited number of participants from universitites and research centres who are not supported by their own institutions can be offered board and/or lodging in a reasonably priced hotel. Requests should be sent to CISM Secretariat by **May 18, 2011** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

The Deutscher Akademischer Austausch Dienst (DAAD) and the Deutsche Forschungsgemeinschaft (DFG) offer support to German students. Please contact:

DAAD, Kennedyallee 50, 53175 Bonn
tel. +49 (228) 882-0
e-mail: postmaster@daad.de
web site: http://www.daad.de/de/kontakt.html

DFG, Kennedyallee 40, 53175 Bonn
tel. +49 (228) 885 2655
e-mail: ing4@dfg.de
web site: http://www.dfg.de

Information about travel and accommodation is available on our web site, or can be mailed upon request.

*For further information please contact:*

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ACADEMIC YEAR 2011

The Germain Session

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

# ADVANCED AND BIO-INSPIRED NANOMECHANICS

Advanced School
coordinated by

**Nicola Pugno**
Politecnico di Torino
Italy

**Udine, *July 18 - 22,* 2011**

## ADVANCED AND BIO-INSPIRED NANOMECHANICS

This course focuses on the latest, often bio-inspired, scientific advancements in the field of Nanomechanics.
The course begins with the opening lecture of the Nobel Laureate H. W. Kroto and continues with a series of introductory lessons, given by well-known scientists, describing the recent discoveries and applications in basic modelling, simulations and experiments in nanomechanics.
Prof. Ruoff will discuss experiments in nanomechanics, mainly his pioneer nanotensile testing apparatus, but also related to energy and environment, novel carbon materials (graphene, nanotubes, others), synthesis and properties of nanostructures, fabrication and properties of nanocomposites and instrument development and technology transition.
Prof. Gao will discuss modelling and simulations in nanomechanics of engineering and biological systems. Engineering systems include deformation, diffusion, growth, grain boundaries, stress evolution and failure in thin films and nanocrystalline materials.
For biological systems, continuum mechanics, statistical mechanics and atomistic simulations will be applied to study how biological materials such as bone, gecko and cell achieve their mechanical robustness through structural hierarchy.
Prof. Buehler will focus on atomistic simulations of deformation and failure of biological materials and structures. By utilizing a computational materials science approach, his goal will be to explain the mechanical properties of biological materials from a fundamental level. An atomistic multi-scale simulation approach, that explicitly considers the architecture of proteins from the atomistic level up to the overall structure, supporting the structure-process-property paradigm of materials science, will thus be presented.
Prof. Gorb. will discuss experimental nanotribology of biological systems. This basic research includes approaches of several disciplines: zoology, botany, structural biology, biomechanics, physics and materials science. The lectures will be mainly focused on biological surfaces specialised for enhancement or reduction of frictional or adhesive forces. Such surfaces are composed of highly-specialised materials and bear surface structures optimised for a particular function. In order to show different functional principles, tests on many different systems to outline general rules of the interrelationship between structure and function will be discussed.
Prof. Persson will discuss new theories on contact mechanics, adhesion, especially in biological systems but also in rubber friction and crack propagation. He will present a new approach to this problem which forms the basis for his theories of rubber friction and adhesion. The basic idea behind the contact theory is that it is very important not to a priori exclude any roughness length scale from the analysis.
Prof. Pugno will present basic theories in nanomechanics, such as (i) the recently developed quantized fracture mechanics (including extensions in dynamic and fatigue) and its applications for calculating the strength of realistic, thus defective, nanostructures, particularly graphene, carbon nanotubes and related bundles, as well as (ii) new formulations of structural nanomechanics and its applications, e.g. for the design of Nano Electro Mechanical Systems (NEMS) or graphene based nansocroll systems.
The course is mainly addressed to PhD Students, Young and Senior Researchers.

## PRELIMINARY SUGGESTED READINGS


Kroto: nanoscience, nanotechnology.
H. Kroto, Simmetry, Space, Stars and $C_{60}$, NOBEL LECTURES, Chemistry 1996-2000, Editor Ingmar Grenthe, World Scientific Publishing Co., Singapore, 2003.

Pugno: nems, quantized fracture mechanics, nanotube bundles, graphene nanoscrolls.
A. Carpinteri, N. Pugno, Are the scaling laws on strength of solids related to mechanics or to geometry? NATURE MATERIALS, 4, 421-423, 2005.

Gao: continuum mechanics, dislocations, robust adhesion, statistical mechanics, atomistic simulations, nanoscroll.
X. Li, Y. Wei, L. Lu, K. Lu and H. Gao, Dislocation nucleation governed softening and maximum strength in nanotwinned metals, NATURE, 464, 877-881, 2010.

Ruoff: nanotensile tests, nanotubes, graphene, ultracapacitors, nanocomposites, nems.
M.F. Yu, O. Lourie, M.J. Dyer, K. Moloni, T.F. Kelly and R.S. Ruoff, Strength and breaking mechanism of multiwalled carbon nanotubes under tensile load, SCIENCE, 287, 637-640, 2000.

Buehler: atomistic simulations, multiscale modeling, density functional theory, biological materials, bio-inspired materials, spider-silk.
S. Keten, Z. Xu, B. Ihle, M.J. Buehler, Nanoconfinement controls stiffness, strength and mechanical toughness of beta-sheet crystals in silk, NATURE MATERIALS, 9, 359-367, 2010.

Gorb: nanotribology, experiments, insect adhesion, plant anti-adhesion, friction, bio-inspired surfaces.
E. Arzt, S.N. Gorb, and R. Spolenak, From micro to nano contacts in biological attachment devices, PROC. NAT. ACAD. SCI. USA, 100, 10603-10606, 2003.

Persson: adhesion, contact mechanics, rubber friction, crack propagation, roughness, fractals.
B.N.J. Persson, U. Tartaglino, O. Albohr and E. Tosatti, Sealing is at the origin of rubber sliding on wet roads, NATURE MATERIALS, 3, 882-885, 2004.


## INVITED LECTURERS

**Harold Kroto** - The Florida State University, Tallahassee FL, USA
Opening Lecture on Nanoscience and Nanotechnology.

**Nicola Pugno** - Politecnico di Torino, Italy
*4 lectures on:*
Theorethical Nanomechanics.

**Huajian Gao** - Brown University, Providence, RI, USA
*6 lectures on:*
Modelling and Simulations in Nanomechanics.

**Rod Ruoff** - The University of Texas at Austin, TX, USA
*6 lectures on:*
Experimental Nanomechanics.

**Markus Buehler** - Massachusetts Institute of Technology, Cambridge, MA, USA
*6 lectures on:*
Atomistic Simulations of Biological Materials and Structures.

**Stanislav Gorb** - Zoological Institute of the University of Kiel, Germany
*6 lectures on:*
Experimental Nanotribology of Biological Systems.

**Bo Persson** - Research Center Juelich IFF, Jülich, Germany
*6 lectures on:*
Contact Mechanics and Adhesion with Applications to Biological Systems.

## LECTURES

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