Open position at the
Université catholique de Louvain, Belgium

MEMS & NEMS for exploring coupled properties of materials at the nanometer scale

Many researches over the last 20 years have shown that when confined to **sub-micron dimensions**, many materials – including metals, semiconductors, ceramics and polymers – exhibit **unexpected and potentially useful properties** completely different from their bulk counterpart.

The measurement of the mechanical behavior of submicron sized specimens is extremely challenging due to difficulties for manipulating samples, for applying small load and for extracting accurate stresses and strains. Our team has developed over the last 10 years a **novel concept of on chip nanomechanical testing**[1,2], to extract the mechanical properties of ductile and brittle materials with thickness ranging from a few µm down to one atom thick 2D material systems. This new concept relies on nanofabrication techniques destined to the production of nanoelectronic devices and NEMS. One key idea is to use internal stress to deform the test sample which is directly deposited on a patterned substrate. A second key idea is to multiply elementary micro- or nano-structure rather than to build on single complex multi-purpose micro- or nano-structure.

Tensile tests and creep tests have been performed up to fracture on **brittle materials** such as SiN, poly and monocrystalline Si, SiO_2, ZnO, ZrO_2, on **ductile thin films** such as Al, AlSi, Ti, Cr, Cu, Ni, Pt, ZrNi and Pd and on graphene. **Size effects** have been demonstrated and elucidated, such as the increase of the yield stress with decreasing film thickness in Al[3] and Pd, the increase of fracture strain of Si up to 5%, the ultra high strain hardening in twinned nanocrystalline Pd[4] films, the large deformation (> 15%) and the high strength - high ductility potential of nano-scale ZrNi metallic glass[5], the creep behavior under heavy ion irradiation of annealed Cu films[6], etc. These results confirm the huge potential of this technique. Now, mechanical stress does not only induce deformation but also gives rise to **coupling effects** such as induced electric field (piezoresistive[7]/piezoelectric effects) or magnetic field (piezomagnetism/magnetostriction).

The aim of the present research project is to push further the original lab-on-chip concept to explore the **coupled physical properties** (piezoresistance, magnetostiction, thermoconductivity, etc.) **of materials thinner than 50 nm including 2D materials** (Si, Ni, VO_2, SmS and SmSe based compounds, AlN, graphene, etc.) in the form of **thin films, nanoribbons, nanowires, or even nanolaminates**. Those systems are used in nanoelectronics as well in nano-coatings introduced in many industrial sectors such as glass, metallurgy, surgery tools, medical prostheses, etc.

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[3] M. Coulombier, A. Boé, C. Brugger, J.-P. Raskin and T. Pardoen, "Imperfection sensitive ductility of aluminium thin films", *Scripta Materialia*, vol. 62, pp. 742–745, 2010.
[4] M. S. Colla, H. Idrissi, B. Amin-Ahmadi, L. Malet, S. Godet, J.-P. Raskin, D. Schryvers, T. Pardoen, "Dislocation mediated hardening and creep in nanocrystalline palladium thin films revealed by on-chip HRTEM in-situ testing", *Nature Communications*, 5 January 2015, doi: 10.1038/ncomms6922.
[5] M. Ghidelli, S. Gravier, J.-J. Blandin, H. Idrissi, N. Schryvers, J.-P. Raskin, T. Pardoen, "Homogeneous flow and size dependent mechanical behaviour in highly ductile $Zr_{65}Ni_{35}$ metallic glass film", *Acta Materialia*, vol. 131, pp. 246-259, 2017.
[6] P. Lapouge, F. Onimus, M. Coulombier, J.-P. Raskin, T. Pardoen and Y. Bréchet, "Creep behavior of submicron copper films under irradiation", *Acta Materialia*, accepted for publication, 2017.
[7] U. K. Bhaskar, T. Pardoen, V. Passi, J.-P. Raskin, "Piezoresistance of nano-scale silicon beams under tension up to 2 GPa", *Applied Physics Letters*, 102, 031911, 2013.

Progresses in these different areas will not only constitute keystones for the development of innovative, reliable NEMS or smart thin coatings, but also lead to advances in the understanding of materials behavior at small length scales in the presence of mechanical loading and chemical agents.

Research covers both theoretical and experimental aspects. This research project is in the framework of fundamental and oriented research programs funded by the European Commission, the Walloon Region and the Communauté française de Belgique. Active collaborations are already established and active in the framework of the proposed project with several universities and research centers (EPFL, UGent, UAntwerpen, CEA, IEMN, Université de Limoges, INP-Grenoble, CEMES-CNRS-Toulouse, IMEC, etc.) as well as with companies (ArcelorMittal, AGC Flat Glass Europe, ESSILOR, Melexis, ST-Microelectronics, SOITEC, etc.).

In this context, UCL is currently seeking for one engineer or master in electrical, material, or applied sciences for pursuing a PhD thesis in that field.

Interested? Please apply with CV to

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ICTEAM is equipped with a complete CMOS processing line (1,000 sqm, 15 M EUR investment) for the rapid fabrication of prototype integrated circuits and the study of novel semiconductor process and devices, as well as with recent physical and electrical characterization equipment in particular for high-temperature (up to 400°C), low temperature (down to 4K) and very high-frequency measurements (up to 110 GHz), software packages for the design and simulation of process, devices, circuits and systems and a network of workstations and microcomputers.
iMMC is equipped with 2 FEG-SEM, a 300 keV TEM, x-ray diffraction, nanoindentation / nanoscratch, chemical analysis tools, macro-mechanical testing, internal stress and adhesion testing devices as well as all usual techniques used for processing, characterization and simulations of materials.