

# Nanomechanics...

*...at the service of mankind...*

**G**alileo Galilei's studies saw the birth of, or at least the initial impetus for science in general and mechanics in particular. Construction engineering was first made possible by the Italian scientist's work on the strength of materials and on the bending, traction and compression of structures. The arrival of nanoscience and nanotechnology has seen renewed interest in this fundamental and traditional research area. Its evolution is there to see in the field of nanomechanics, that is the mechanics of nanomaterials or nanoscopic structures. This is also true in Italy, where Galileo's legacy is still alive. We have indeed been working in the field of mechanics for over 10 years now here in Torino. The following is a quick summary of our studies, however for further information, please see our 2007 publication: 'The Nanomechanics in Italy'.

At first we studied the development of new theories for nano-electromechanical systems (NEMS), based on nanotubes and graphene, later validating our results by numeric modelling and with the development of a prototype. The way NEMS can be integrated in devices - in the order of  $10^{12}$  per  $cm^2$ , and their working frequencies in the gigahertz range provide promising characteristics for future applications, eg supercomputers and super-sensors.

Nanotubes and graphene are of great interest above all because of their mechanic strength - some 100 times that of high-resistance steel. This is indeed a time of dreams, whether or not they can be realised, like the futuristic project of the space elevator. We have therefore worked on a flaw-tolerant design for this,

considering various structures and materials, without neglecting the role played by defects, and exploiting the possibilities provided by nanotubes and graphene - with futuristic applications that are not confined to the space elevator but include suspension bridges, like the planned bridge over the Strait of Messina in Italy.

Thus, we can begin to understand how to bring ideal properties from the nanoscale to the macroscale, something that was impossible for scientists until quite recently. For this, it is nature herself who is suggesting the use of hierarchical architectures. For example, silk spun by spiders is remarkably tough and flaw-tolerant and bones are self-healing - a property without which we could not even survive but which we are only now beginning to understand how to mimic in engineered materials. The applications are remarkable, for example the possibility to develop bio-inspired super-tough materials to avoid catastrophes, both man-made, for example terrorism, and natural, for example earthquakes.

Just like spiders, there is another animal that uses van der Waals forces to its own advantage to stick to walls and ceilings better than any other. It is the Tokay gecko. The literature is full of studies on this topic, so we have strived to get a better understanding of the underlying physics and to design bio-inspired super adhesive surfaces. What is specific in our approach, as in the case of the space elevator, is that we are also looking at scaling-up; again, the applications are noteworthy, for example a 'Spiderman' suit for astronauts to work safely in space.

The other side of the adhesion coin is anti-adhesion, or self-cleaning. Here,

lotus leaves have been our guide. Their hierarchical topology is the key to their remarkable properties. We have developed a hierarchical theory to design bio-inspired super anti-adhesive surfaces that are self-cleaning, and we are now in a position to produce them. Amongst the important applications is the design of airplane wings with the capacity to avoid a build-up of ice.

Finally, we would like to publicly thank the European Research Council (ERC) for the award of an IDEAS Starting Grant in 2011 for our bio-inspired hierarchical super-nanomaterials project. Our mission statement is a simple one: as the history of past eras - the Stone Age, the Bronze Age, the Iron Age - teaches us, the new materials on which we are focusing can, if well designed, improve man's quality of life significantly. This is what distinguishes us and, in the end, it is what spurs us on. If scientific research does not have this aim, it is pointless and even pernicious. Our first ERC-sponsored paper, in collaboration with the MIT in Boston, has earned us the cover of 'Nature'.



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