OUTSTANDING RESULTS
INSTITUTE OF TECHNICAL PHYSICS AND MATERIALS SCIENCE

Characterization of grain boundaries of graphene grown by chemical vapor deposition and atomic scale processing of graphene

Graphene is a single atom thick sheet of the well known graphite. Numerous exciting properties emerge from the truly atomic thickness of this material which make it a possible candidate to be the replacement material for the silicon used in microelectronics and in the mass production of flexible touch screens, too. The material can be produced cost effectively by chemical vapor deposition (CVD) on the surface of copper. The researchers of the nanostructures Research Group have shown for the first time that the electric properties of the graphene sheets grown by CVD deteriorate due to the double coordinated carbon atoms occurring in the region of the grain boundaries.

In the research direction targeting the realization of graphene based digital nanoelectronics they patterned for the first time with atomic precision and crystallographic orientation control the CVD grown graphene. They used their method developed earlier for the atomic precision lithography of graphene. On the nanoribbons of a few nanometers (a millionth part of a millimeter) in width they have found novel magnetic ordering stable at room temperature which they explained by theoretical modeling. These results may open up new paths in the field of spintronics.


One may well observe the strong localization occurring on the vacancies (marked by red circles) of the disordered grain boundary and the strongly decreased transmission to the left hand side of the grain boundary. (P. Vancsó et al., Appl. Surf. Sci. 291 (2014) 58; DOI: 10.1016/j.apsusc.2013.09.127)

Papers:

Graphene superlattice

Graphene is an elastic membrane and at the same time a perfect crystal. The researchers have exploited this unique property-combination to design graphene nanostructures with novel electronic properties. They found that the electronic structure of graphene can be substantially altered by inducing nanometer scale periodic out-of-plane deformations into its atomic structure. By using strain-engineering they have realized for the first time experimentally such nanometer scale periodic modulation of a graphene membrane, demonstrating that the electronic properties of graphene can be controlled by nanoscale periodic rippling. Due to the rippling of the atomic structure a so called electronic superlattice emerged, which can be at the basis of several nanoelectronic applications. Moreover, a new regime of membrane mechanics has been accessed, where the scale of deformations is comparable to the lattice constant, and the rules of classical continuum mechanics can no longer be applied. To interpret our experimental findings we have developed a theoretical model based on the quantum mechanical treatment of the carbon-carbon
bonds, laying the foundations of the mechanics of nanoscale deformations of atomic membranes. The results have been achieved in collaboration with groups from Korea and the United States.

Scanning tunneling microscopy image of graphene nanoripples (left), the atomic scale model of their structure (middle), and the electronic superlattice observed by tunneling spectroscopy (right).

Publication:


Colors without pigments

The wings of butterflies may be charmingly colorful. These colors are chemical and physical by origin: they are originated from the combined effect of the pigments and of a particular nanocomposite, known as the photonic crystal nanostructure. By the alteration of the typical size or the refractive index ratio of the nanocomposite the wavelength of the reflected light can be changed. This results the alteration of the coloration. Butterfly wing are covered with microscopic chitin scales of 50 – 100 microns (a thousandth part of a millimeter) which are the origin of the wing coloration. The color of the scales depends only on the properties of the photonic nanoarchitecture. By changing the gas/vapor in the nanovoids of the structure to a material with a different refractive index, a color change appears. The amount of the color change is function of vapor concentration and type. This process is complete reversible, restoring the properties of the ambient, results in the return of the original color. Monitoring the spectral change obtained to different gas / vapors, one can conclude the material and its concentration. Our current investigations aim to reveal the physical basis of this process for making possible the development of chemically selective sensors with optical readout, working in normal room ambient. The butterfly wing scale thickness is in the range of micrometers still it is able to produce intensive coloration. This may lead to the development of thin displays or even paints without chemical dyes. Combining with the water repellent effect, several promising applications are foreseen. Scales with different nanostructure generate characteristic response signals. Using a proper data processing we could reach a step closer to selective intelligent and miniature sensors.
Publications:
L.P. Biró and J.P. Vigneron
Photonic nanoarchitectures in butterflies and beetles: valuable sources for bioinspiration
Bálint Zs., Kertész K., Piszter G., Vértesy Z., Biró L. P.
The well-tuned Blues: the role of structural colours as optical signals in species recognition of a local butterfly fauna (Lepidoptera: Lycaenidae: Polyommatinae)
Kertész K., Piszter G., Jakab E., Bálint Zs., Vértesy Z., Biró L. P.
Color change of Blue butterfly wing scales in an air - Vapor ambient

Blue structural wing coloration on Polyommatus icarus butterfly (left). The other side of the wing is colored by pigments (right).

Scanning electron microscope image of a single scale (left), photonic crystal type structure inside the scale (right)
Water droplets on Morpho aega wing. The micro and nano-structure of the scales makes the wing surface superhydrophobic.

**Biogenic bone substitution material from eggshell**

The synthetic hydroxiapatite (HAp) is one of the most used bioactive implant material. The properties of hydroxiapatite prepared from biogenic materials are better than the properties of material prepared through synthetic routes. The novel preparation technology of disposed eggshells is cheaper, environmental-friendly compared with preparation method of synthetic hydroxiapatite. The HAp powder, fiber and 3D polymer/HAp form of bone substitution material may be applied as special grafts in maxillofacial and oral surgery or surgical corrections. On the other hand, the bioactive HAp is a potential coating for implants. The natural HAp contains the most important trace elements as magnesium and strontium, which promote the bone regeneration and prevent osteoporosis. The efficiency sintered grafts have been demonstrated by in vitro and in vivo studies in the frame of international co-operations.