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ISOLDE takes big science to nanoscale

New materials that could replace the semiconductors currently used in Blu-ray and other electronic devices, cost-efficient silicon for a new generation of solar panels, innovative investigation techniques for archaeology, biophysics and biochemistry…behind all this are the studies using nuclear hyperfine interactions. Of paramount importance in such studies is the availability of a large variety of radioactive ion beams: at CERN, these are produced by the ISOLDE facility.

Students from the University of Leuven and ITN Lisbon working at ISOLDE on a technique used to locate impurities in materials.

Nuclear hyperfine interactions and their wide range of applications were the focus of the third Joint International Conference on Hyperfine Interactions and International Symposium on Nuclear Quadrupole Interactions, held at CERN from 12 to 17 September. The conference featured theoretical talks but also studies on magnetic materials, semiconductors, thin films, nano-structures and quantum optics, as well as on topics related to archaeology, biology, chemistry and medicine.

Researchers from ISOLDE, the on-line separator for radioactive ion beams at CERN, actively participated in the conference. The facility is unique for its ability to generate a large variety of such probe-isotopes, spanning a wide range of half-lives, at high intensity. Such radio-probes can be used in low concentrations and do not to alter the material's structure as much as alternative methods. "ISOLDE produces isotopes, which we use as radioactive probes: once we have implanted them in a material, such as a superconducting solid or a protein, they start experiencing the local environment, and through their decay we can get valuable information about their place in the material lattice", explains Karl Johnston, Solid State Physics Coordinator at ISOLDE, and one of the organisers of the Conference.

In recent years, hyperfine interaction measurements performed in conjunction with optical spectroscopy and lattice location studies have provided important insights into the structure of materials. The technique proved to be particularly powerful in studying the nature and origin of imperfections in the lattice structure of semiconductors, such as those used in solar cells. "For cost reasons the quality of silicon used for solar cells is one order of magnitude lower than that used for computer chips. This creates efficiency problems due to defects in the lattice: we may not be able to eliminate these defects, but by understanding them we hope to be able to reduce their detrimental impact, thus making the processing more cost-efficient", confirms Johnston.

Radio-probes delivered by ISOLDE are also being used to study a potentially very interesting new material, zinc oxide (ZnO). "In optoelectronics applications, such as the lasers used for Blu-ray devices, ZnO is seen as a good candidate for replacing gallium nitride (GaN), which is currently used", explains Johnston. "While with GaN it is difficult to get rid of imperfections in the lattice – making it costly to produce consistently high-quality devices – with ZnO you can grow crystals with few defects. In addition, ZnO has a very high optical efficiency: if you send a laser into it, it will glow with little help", says Johnston.

Despite these extremely promising properties, ZnO does not seem to be ready for use just yet. In fact, it is difficult to dope in a symmetric way: n-type doping is readily achievable but p-type doping has proved extremely difficult; both dopings are required to produce a useful device such as a transistor. In addition, some of the magnetic properties of ZnO, which have recently been studied by Johnston and his colleagues, do not seem suitable for future use of the material in spintronics (see box) "Other materials are now receiving the attention of the scientific community. At ISOLDE, 19 experiments are either already studying or have submitted letters of intent to study these topics, and we certainly haven't heard the last word on what hyperfine interactions can tell us", concludes Johnston.

Spintronics

Spintronics (a neologism meaning "spin transport electronics") is an emerging technology that exploits the intrinsic spin of the electron and its associated magnetic moment, in addition to its fundamental electronic charge, in solid-state devices.

by Roberto Cantoni