Low dimensional systems

Professor Thomas Greber

We study objects like **zero-dimensional endofullerene** molecules and **two-dimensional (2D) boron nitride** layers in view of their functionality as nano-materials. Single-molecule magnetism is the focus of the fullerene research, where we apply x-ray absorption and a sub-Kelvin superconducting quantum interference device. In the activity of the 2D materials, we grow the highest quality boron nitride on substrates up to the four-inch wafer scale with chemical vapor deposition, subsequent exfoliation, and implementation in devices. At UZH Irchel, we use a dedicated clean room, optical microscopy, inkjet printing, and surface science tools such as low-energy electron diffraction, photoemission, and scanning tunneling microscopy for these purposes. At the Swiss Light Source, we perform photoemission and x-ray absorption spectroscopy experiments.

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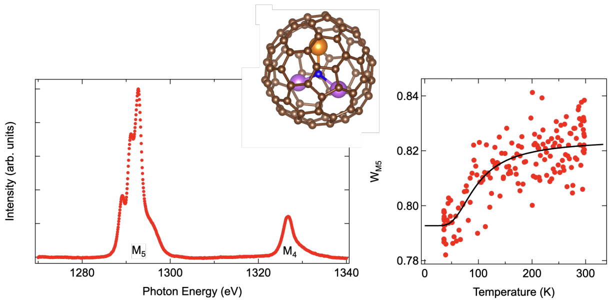
Orientation of endohedral clusters

Endohedral fullerenes are small atomic clusters encapsulated by a fullerene carbon shell. For the case of $DySc_2N@C_{80}$ Dy turns out to display as a single magnetic ion. At low temperatures Dy^{3+} may maintain the orientation of the magnetic moment for hours. The orientation follows the ligand field and thus the Dy-N bond axis. Given this single-molecule magnet behavior, it is vital to know the Dy-N bond axis orientation in space. This orientation can be obtained from resonant x-ray absorption spectroscopy (XAS) experiments and comparison to multiplet calculations for different Dy-N orientations relative to the x-ray polarisation vector. The figure shows XAS data of $DySc_2N@C_{80}$ on a platinum surface. The spectral weight of the Dy M_5 edge depends on temperature. Since multiplet theory predicts different weights of the Dy M_5 edge as a function of the angle between the x-ray incidence and the Dy-N axis this indicates that the experiment is sensitive to the endohedral orientation, which is isotropic at room temperature and which shows a tendency of Dy-N axis orientation parallel to the surface at low temperature.



Resonant x-ray absorption spectrum at the Dy $M_{4,5}$ edge of $DySc_2N@C_{80}$ on a Pt(111) surface (left). The spectral weight of the M_5 edge W_{M5} depends on the temperature and indicates the onset of endohedral rotation at about 90 K. The solid line is a thermodynamic model that describes the endohedral motion (right panel). The inset depicts one endohedral fullerene molecule with a diameter of 1.1 nm. Dysprosium yellow, nitrogen blue. Data R. Sagehashi et al.

This shows that x-ray absorption experiments allow highly sensitive in-operando studies of the orientation of endohedral clusters.

The experiments were performed at the photoemission and atomic resolution laboratory (PEARL) bending magnet beamline at the Swiss Light Source. The project is a collaboration with the Institut für Festkörper- und Werkstoffforschung IFW in Dresden, the Chiba University, and the Paul Scherrer Institut in Villigen.

Highlighted Publications:

- The Winner Takes It All: Carbon Supersedes Hexagonal Boron Nitride with Graphene on Transition Metals at High Temperatures
  A. Hemmi *et al.*, small 18, 2205184 (2022)
- X-ray absorption measurements at a bending magnet beamline with an Everhart-Thornley detector: A monolayer of $Ho_3N@C_{80}$ on graphene
  W. C. Lee *et al.*, J. Vac. Sci. Technol. A 40, 053205 (2022)
- Synthesis of a magnetic π-extended carbon nanosolenoid with Riemann surfaces
  J. Wang *et al.*, Nature Comm. 13, 1239 (2022)