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IPCMS NEWS

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Editorial

As 2026 approaches its end, the research community is experiencing a certain buzz amid broader national debates on the budget and the presidential campaign, where the role of scientific research in France is being discussed. To this end, numerous stakeholders in the field are alerting politicians to a situation that could become critical in the medium term. As it more directly concerns our laboratory, the new CEO of the CNRS is launching his program to "transform science, strengthen science, and promote science." In particular, the emphasis is on interdisciplinarity and disruptive innovation addressing major contemporary challenges such as artificial intelligence, quantum sciences, and new materials, as well as on the desire to build on a strong network of international collaborations—a goal that is undoubtedly welcome at a time when so many conflicts are dividing the world.

At the same time, the University of Strasbourg is launching its new "Contract on Objectives, Resources, and Performance" for the next three years. It reflects the institution's core values : intensive multidisciplinary research, cross-border collaboration, strong appeal as a hub in the heart of Europe, and investment in research infrastructure.

The IPCMS is playing its part in this effervescence and continues to contribute to the visibility sought by our supervisory organisations. Several projects have been selected within the CNRS's pre-incubation program, notably a project on microwave spectroscopy for the analysis of magnetic materials, and another on a new triplet-recycling light-emitting system for OLEDs. The startup Lumensium is a winner of the i-Lab 2026 national innovation competition. At the European level, we commend the EIC-PATH FINDER REMMIA collaborative project on magnet recycling. IPCMS is also developing the CNRS pre-development project SyMuL with the University of St. Andrews to design new molecular emitters for OLEDs. In the same domain, researchers of the lab are active within the recently launched International Research Laboratory OPHELIA, between the CNRS and the OPERA Center at Kyushu University, Japan.

As usual, this issue of IPCMS News features a selection of recent works highlighting the multidisciplinary and transdisciplinary scientific projects being conducted at the laboratory. We present an innovating method to detect spin waves and the design of a new sub-microscale magneto sensors that enlarge the field of magnonics. Nanofabrication facilities were also used to build microscale magnetic tunnel junctions exhibiting quantum transport. Atom diffraction is a new sensitive and non-destructive probe of atom-surface interactions that was recently reported and state-of-the art ab initio calculations were advantageously exploited for the investigation of structural or chemical modifications in 2D materials. Multiscale and multi-techniques approaches are very powerful to characterize matter. A recent study demonstrates the value of correlative in situ approach for deciphering the formation pathways of functional materials. Formation of new materials is also the purpose of inorganic chemists who developed an original soft solid-state chemistry to functionalize layered perovskites, whereas other colleagues investigated the relationships between defect chemistry, electronic transport and ferroelectric properties of oxide thin films. In addition, as an example of applications of nanomaterials, you will read about mesoporous silica particles that are very promising nanocarriers for targeted cancer therapies.

Enjoy reading !

Pierre Rabu, Director



Ion beam etcher equipped with a SIMS for etch monitoring and a sputtering system for SiO_2 layer encapsulation. Equipment used in particular for the fabrication of magnetoresistive devices.
(Project Range - Région Grand Est]

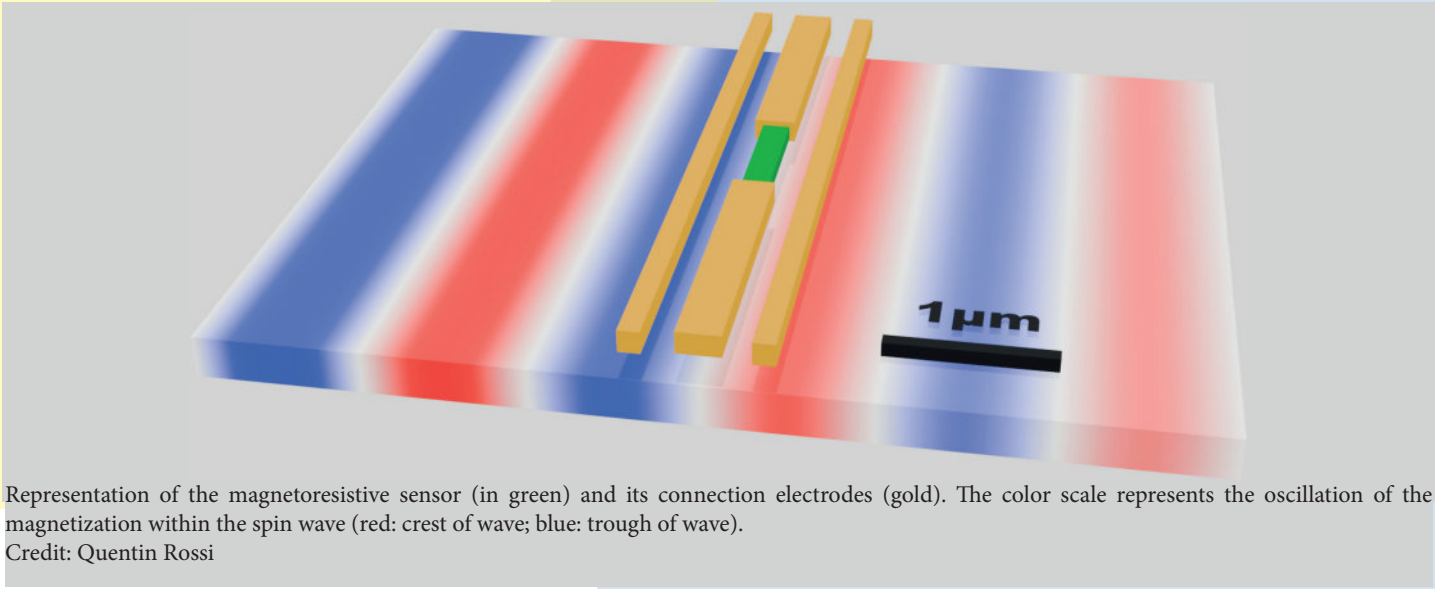
crédit photo : STnano Facility

Sub-micronic magnetoresistive detection of guided spin waves

Spin waves, or magnons, that are local vibrations in the magnetisation have recently been proposed for new information processing architectures known as magnonics: it would combine the ease of interconnection of wave systems with the magnetic information storage capabilities. Such spin waves need to be interfaced with microelectronic circuits by converting them into an electrical signal at a nanometric scale relevant to current technologies. The techniques used to date - such as optical imaging or inductive detection - have struggled to capture these waves at sub-micrometric scales.

Researchers from our institute and the Service de Physique de l'État Condensé (CEA Saclay/CNRS), have developed a novel method to efficiently detect spin waves as part of the national PEPR Spin program. They integrated a giant magnetoresistance (GMR) sensor directly beneath a waveguide. When the waves pass close to the sensor, the magnetisation of one of the sensor's layers oscillates slightly which in turn changes the sensor's electrical resistance: this variation is converted into a measurable signal at frequencies of a few gigahertz. Using this device, a signal fifty times larger than that obtained with the inductive method at equivalent detection surface area has been measured. This demonstrates the effectiveness of GMR sensors for probing spin waves at very high frequencies and at the nanometer scale (by using more sensitive tunnel magnetoresistance sensors, it would even be possible to increase the signal further). Numerical micromagnetic simulations that accurately reproduce the measurements confirmed these results.

In the long term, this breakthrough paves the way for ultra-compact spin-wave sensors capable of operating in extreme regimes—below 100 nm or even for waves generated by thermal fluctuations. It also brings magnonics closer to integration into conventional electronic circuits, enabling the design of new architectures that are faster and more energy efficient.

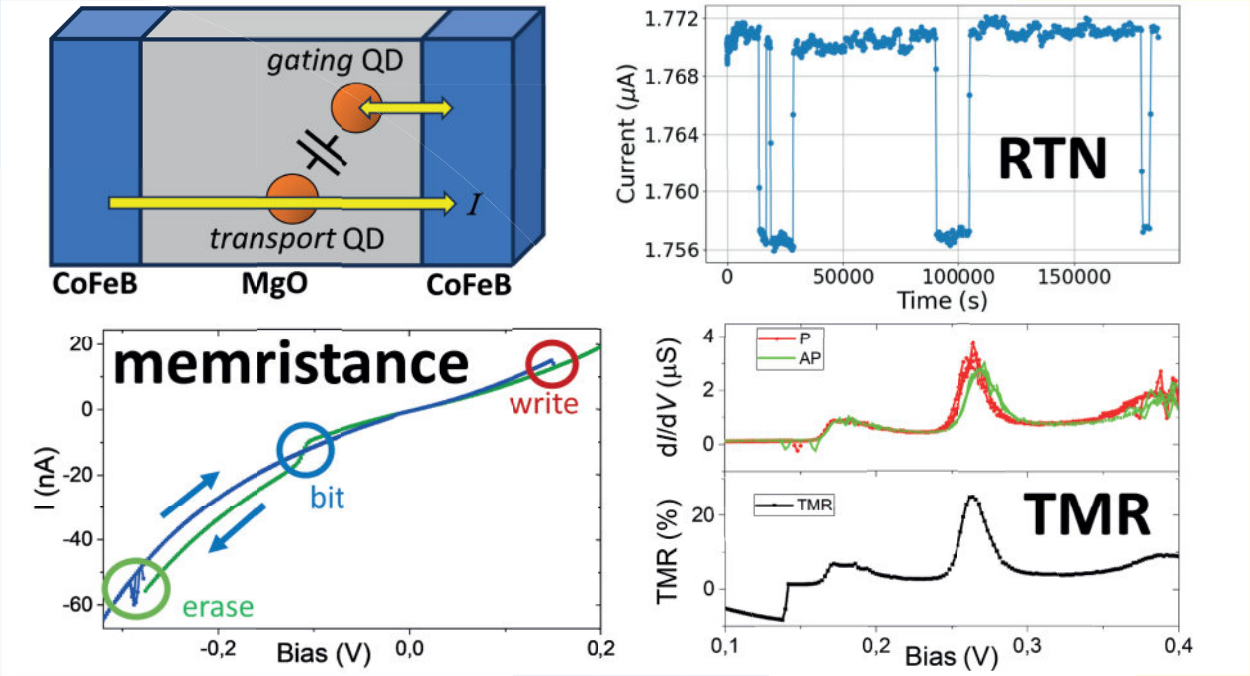


Representation of the magnetoresistive sensor (in green) and its connection electrodes (gold). The color scale represents the oscillation of the magnetization within the spin wave (red: crest of wave; blue: trough of wave).
Credit: Quentin Rossi

Q. Rossi, D. Stoeffler, G. De Loubens, H. Merbouche, H. Majjad, Y. Henry, I. Ngouagnia, A. Solignac, M. Bailleul, *Sci. Adv.* ***2025***, *11, eadx4126*. DOI: https://doi.org/10.1126/sciadv.adx4126

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Carbon nanodots confer quantum spintronic properties to a standard magnetic tunnel junction



Transport across model junctions built by using atomic tip or lateral techniques can generate exotic quantum signatures. However, so far, a viable industrial pathway for atom-driven electronics has been lacking. Here, we demonstrate that a commercialized device platform can help to fill this nanotechnological gap. To do so, we utilize magnetic tunnel junctions, which are used as the read head in disk drives, and as non-volatile ultrafast memories called MRAM. To obtain quantum spintronic functionalities, we insert carbon atoms within the device's ultrathin MgO tunnel barrier. Our conducting tip atomic force microscopy investigations reveal that this generates nanotransport channels of strongly enhanced electrical conduction. This means that electron transport across our microscale magnetic tunnel junctions will proceed along nanoscale paths, much like in a model junction. We observe how resonant tunneling causes large conductance peaks, which are bias-shifted upon switching from the parallel to antiparallel orientation of electrode magnetization. The resulting large magnetoresistance peaks at the bias shift position constitute the signature of spin-polarized Coulomb blockade. This is due to spin accumulation onto a 'transport' Cnanodot that defines the nanotransport path. We also observe the concurrent presence of a spectrally localized, nonlinear current noise and a persistent electrical memory effect. We propose that the 'transport' Cnanodot be capacitively coupled to a spatially proximate 'gating' C nanodot. The charging and discharging of the gating C nanodot would account for the memristance effect that is observed. This nanoscale dual-dot description of quantum transport across spin states within a microscale magnetic tunnel junction should stimulate further research toward maturing spintronics into a viable quantum technological track.

M. Lamblin, V. Da Costa, L. Joly, B. Chowrira, L. Petitdemange, B. Vileno, R. Bernard, B. Gobaut, S. Boukari, W. Weber, M. Hehn, D. Lacour, M. Bowen, *Nano Lett.* ***2025,*** *25, 18026−18035.*
DOI: https://doi.org/10.1021/acs.nanolett.5c03672

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Sharp Diffraction Patterns from Atoms Passing Through Graphene

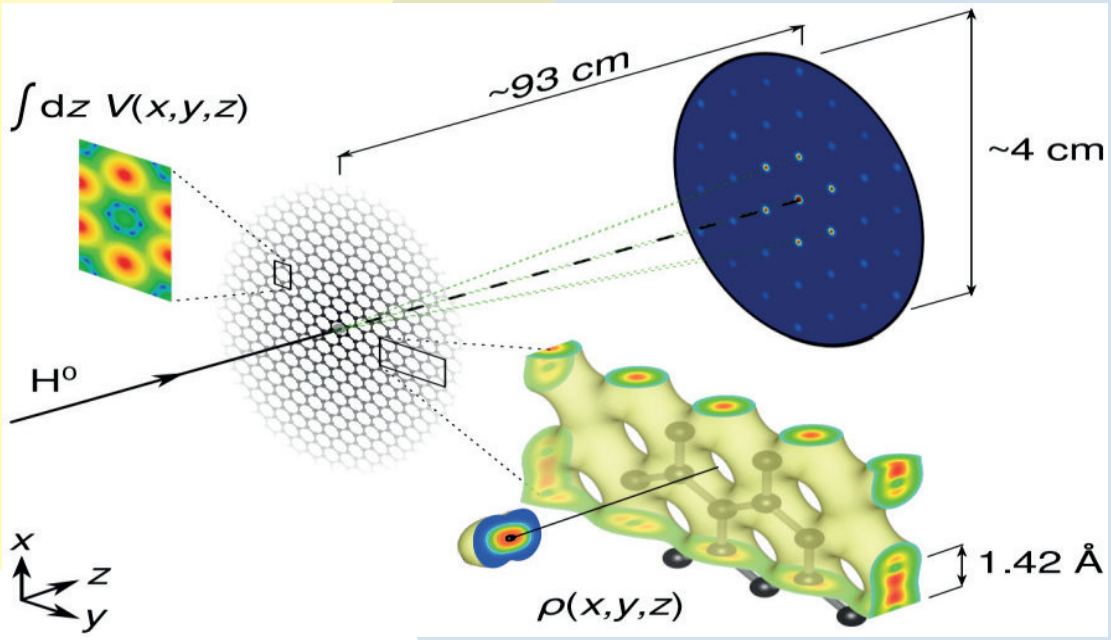
Diffraction, the spreading of waves as they pass through an obstacle, is familiar from light and X-rays. Less well known is that atoms also behave as waves, an idea first proposed by Louis de Broglie a century ago. While electron diffraction rapidly became a cornerstone of materials science, observing the diffraction of neutral atoms transmitted through a crystal long remained an experimental challenge, because their interaction with the material easily destroys the wave coherence.

In collaboration with an experimental team in Belgium, we have now overcome this obstacle by sending fast hydrogen atoms through a suspended single layer of graphene.

Once its surface had been carefully cleared of contaminants, we recorded remarkably sharp hexagonal patterns that directly reveal the crystal structure and orientation of individual graphene domains. Time-of-flight measurements further showed that the diffracted atoms lose virtually no energy, cleanly separating coherent diffraction from inelastic scattering.

Beyond this experimental achievement, the study reveals the extraordinary sensitivity of atomic diffraction to the microscopic interaction between hydrogen atoms and graphene. Reproducing the measured intensities demands state-of-the-art ab initio calculations, based on density functional theory and the full three-dimensional interaction potential, whereas simpler models fail. This turns neutral-atom diffraction into a powerful new probe of atom–surface interactions.

The approach opens promising avenues for characterizing defects, strain and chemical modifications in two-dimensional materials, and paves the way toward a new form of surface spectroscopy, as well as future applications in matter-wave interferometry and fundamental physics.



Schematic illustration of the coherent diffraction of a beam of neutral hydrogen atoms (H^0) transmitted through graphene.

P. Guichard, A. Dochain, R. Marion, P. de Crombrugghe de Picquendaele, N. Lejeune, B. Hackens, P. -A. Hervieux, and X. Urbain
Physical Review Letters, ***2026***, *135, 26340*.
DOI : https://doi.org/10.1103/wdx6-mrvm

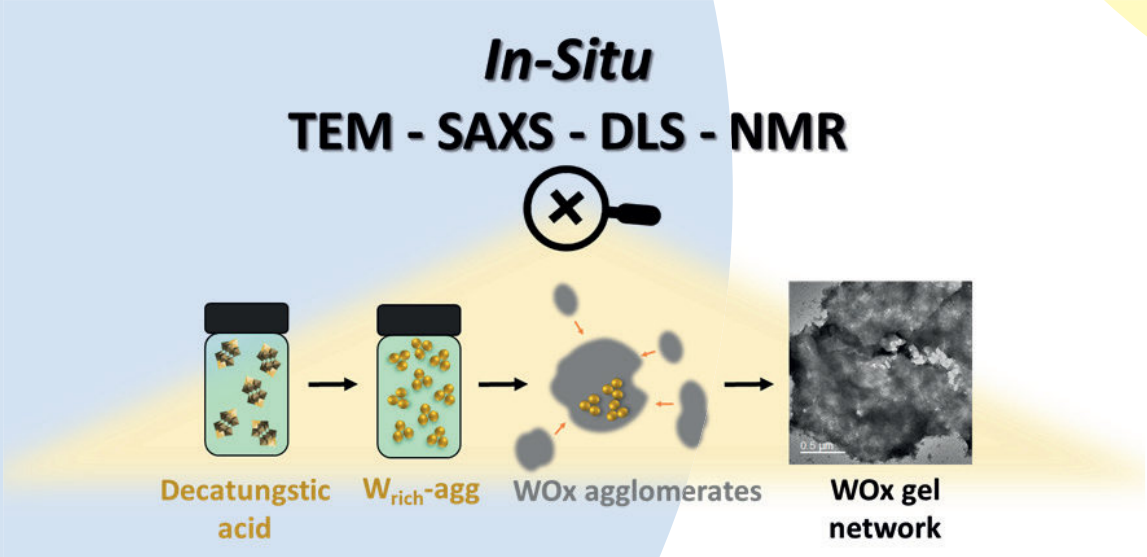
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Unravelling the formation of metal oxide-based materials through correlative in situ approaches

A fruitful collaboration between several CNRS teams, within the framework of the ITI QMat and the USIAS of the University of Strasbourg, has provided a detailed picture of the formation of tungsten oxide gels through a chimie-douce route. By combining recent advances in liquid-phase transmission electron microscopy (LP-TEM) with complementary scattering and spectroscopic techniques, the study reveals the mechanism leading from molecular precursors to the final gel network.

The evolution of the precursor solution was monitored using time-resolved LP-TEM, dynamic light scattering (DLS), small-angle X-ray scattering (SAXS), and liquid-state nuclear magnetic resonance (NMR). NMR and SAXS show that decatungstic acid is the last soluble species detected before gelation, identifying it as the final reservoir of dissolved tungsten. In situ LP-TEM provides direct real-space evidence for a series of transient structures evolving across multiple length and time scales. In particular, previously unobserved W-rich aggregates and WOx-rich assemblies appear as localized, highly acidic environments where polytungstate species can partially break down, generating colloidal precursors that play a key role in gel nucleation. These local observations are consistent with the global information obtained by DLS and SAXS. Together, these datasets reveal the progressive formation of a fractal network and support a reaction-limited cluster-cluster aggregation mechanism for the nucleation and growth of the final gel.

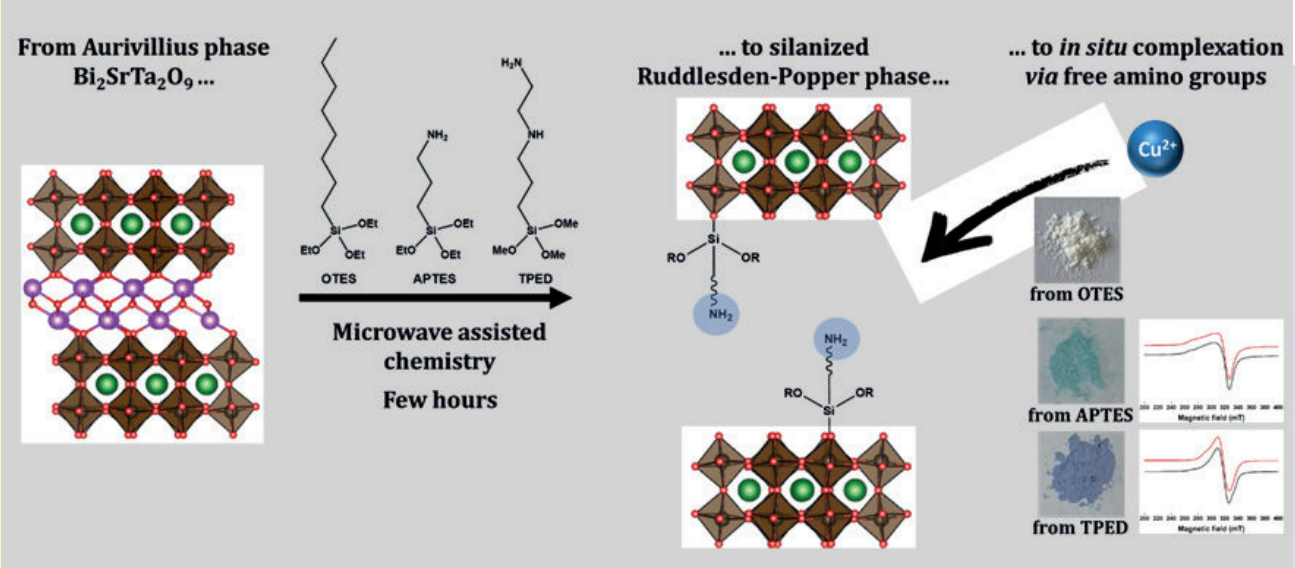
Beyond the mechanism investigated, this work highlights the value of correlative in situ approaches for deciphering complex material formation pathways. Combining microscopy, scattering, and spectroscopy allows to bridge local and global observations and identify transient species that remain inaccessible to conventional ex situ characterization. Such multiscale approaches should prove particularly valuable for understanding the formation of other inorganic and hybrid materials.



C. Sidhoum, D. Ihiawakrim, M. Haouas, D. Constantin, F. Schosseler, M. Odziomek, K. Vertchik, A. Leforestier, C. Sanchez and O. Ersen, *Chem. Mater.* ***2025,*** *37, 5454−5465*
DOI : https://doi.org/10.1021/acs.chemmater.4c03003

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Soft Chemistry opens new coordination pathways in layered perovskites



The concept of chimie douce (soft chemistry), pioneered by Jacques Livage, has profoundly transformed the design of functional inorganic solids. Instead of relying on high-temperature synthesis, it exploits low-energy topochemical transformations that preserve inorganic frameworks while progressively introducing new functionalities. This bottom-up strategy enables the rational design of hybrid materials with independently tunable structure and properties.

Layered oxides are particularly well suited to this approach because their interlayer space provides a confined, chemically accessible environment that can be modified without disrupting the host lattice. Here, chemists from IPCMS, in collaboration with ICCF (Clermont-Ferrand) and the Institut de Chimie de Strasbourg, extend the chimie douce approach to the Aurivillius layered perovskite $Bi_2SrTa_2O_9$. They develop a rapid microwave-assisted silanization method that allows to covalently graft organosilanes into the interlayer galleries while preserving the oxide's crystallinity and layered structure.

Using X-ray diffraction, infrared spectroscopy, elemental analysis and solid-state NMR, the authors show that organosilanes are anchored through stable Si–O–Ta bonds with limited siloxane condensation. More importantly, amino-functionalized silanes retain accessible pendant amine groups after grafting, unlike conventional intercalation methods that consume these functionalities through interactions with the inorganic framework. These preserved amino groups enable genuine post-synthetic functionalization. As a proof of concept, Cu^{2+} ions were coordinated within the interlayer space, as confirmed by UV–Visible and EPR spectroscopies.

By combining microwave-assisted synthesis with controlled covalent functionalization, this work further illustrates the power of soft chemistry for engineering layered hybrid materials. It broadens the toolbox for designing multifunctional organic–inorganic solids, creating reactive coordination sites that remain accessible while preserving the crystal architecture. It opens perspectives for applications in heterogeneous catalysis, chemical sensing, metal-ion capture, environmental remediation and luminescent materials.

Reference : P. Chapel, T. Henry, F. Payet, C. Leuvrey, F. Leroux, N. Parizel, P. Rabu, G. Rogez, *Appl. Clay. Science*, ***2025***, *278*, *108017*
DOI : https://doi.org/10.1016/j.clay.2025.108017

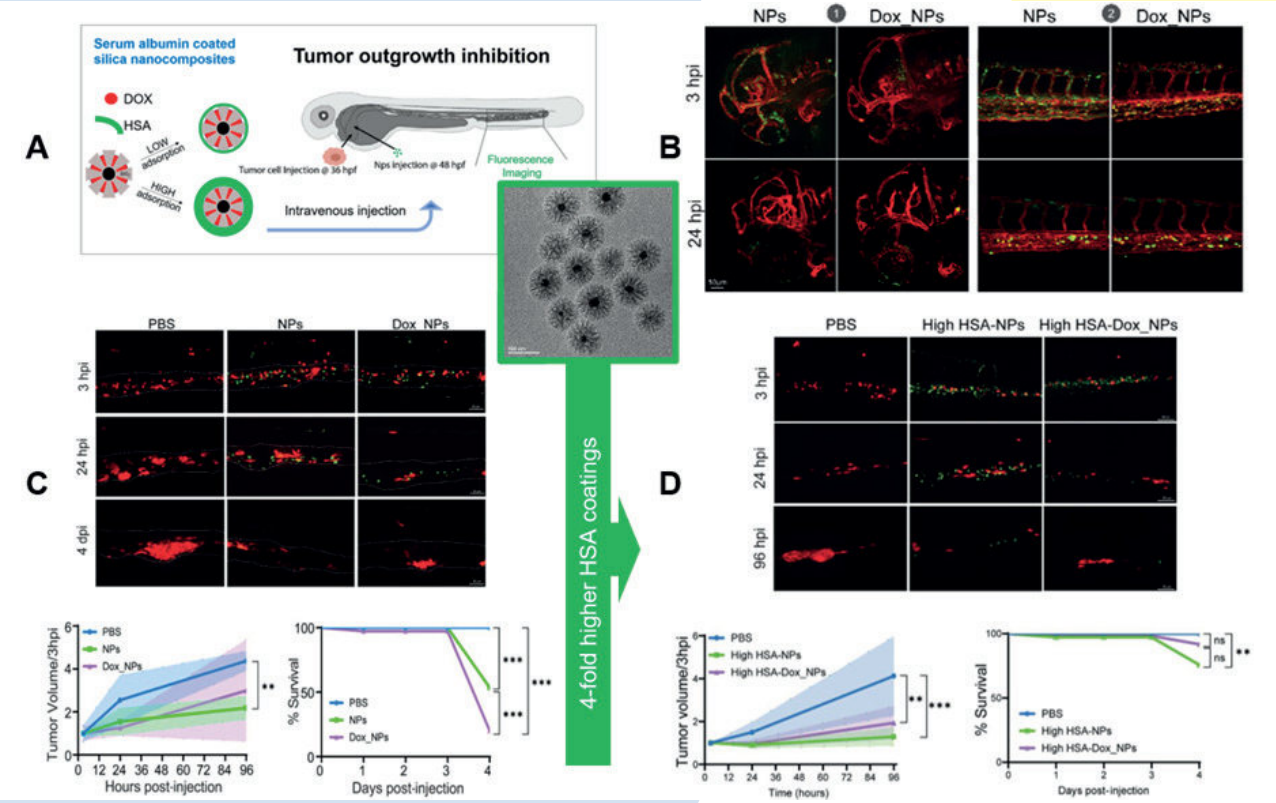
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In Vivo Behavior of Serum Albumin-Coated Stellate Silica Nanocomposites in Zebrafish Tumor Models

Mesoporous silica nanoparticles (NPs) are promising nanocarriers for targeted cancer therapies. Core shell NPs such as iron oxide @ stellate mesoporous silica (IO@STMS) NPs combine a porous silica shell for drug loading with a magnetic core for induced hyperthermia treatments and MRI imaging. To date, their in vivo effects and toxicity remained poorly understood especially regarding their ability to inhibit tumor outgrowth model. This work evaluated the impacts of such nanoconstructs in a zebrafish metastasis model.

The core shell NPs were synthesized by inorganic synthesis methods such as thermal decomposition for the core and sol-gel reaction with surfactant-induced pore formation for the porous silica shell. They were further coated with human serum albumin (HSA) and loaded with or without the antitumoral drug doxorubicin (DOX). In vitro, DOX-loaded NPs showed higher toxicity toward zebrafish melanoma cancer cells as expected. In vivo, in healthy embryo zebrafish, NPs injected intravascularly rapidly circulated through the blood and accumulated near vascular endothelial cells and macrophages. In melanoma tumor models, remarkably, the NPs reduced tumor metastatic outgrowth in vivo, even without DOX loading. Increasing HSA coating further enhanced their anti-metastatic activity and improved embryo survival. These findings highlight IO@STMS NPs as promising tools for treatments by passive accumulation of such nanocarriers, and local drug delivery.

This work was achieved in collaboration with the group of Dr. Jacky Goetz (Tumor Biomechanics Lab, INSERM, CRBS, University of Strasbourg, France), and with Dr. Mariana Tasso (Institute of Nanosystems, National University of San Martín, Buenos Aires, Argentina) especially regarding the biological assays.



A) Objectives of the work. B) Fluorescence imaging of HSA NPs (green fluorescent), loaded or not with DOX in healthy zebra fish (red fluorescent vascular system). C,D) Fluorescence imaging and quantification of tumor growth inhibition of zebrafish homing melanoma cancer cells (red fluorescence). Scale bar : 50 µm.

Reference : N. Asokan, V. Mittelheisser, A. Jablonski, A. Adam, J. Bizeau, S. Harlepp, V. Hyenne, O. Lefebvre, J. G. Goetz, M. Tasso, D. Mertz., *Nanoscale* ***2025****; 17 (48): 27959–27974*
DOI: https://doi.org/10.1039/d5nr02444g

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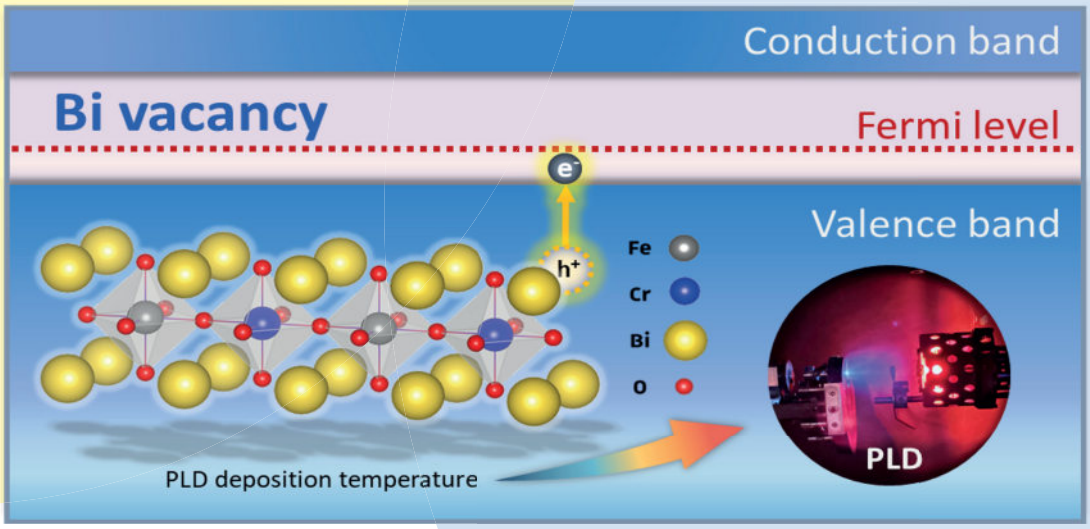
Impact of Bi vacancies on the polarization and transport properties of Bi_2FeCrO_6 thin films

This work presents an insight in the defect engineering of multiferroic thin films for optoelectronic applications. Specifically, it focus on the Bi2FeCrO6 (BFCO) double perovskite, a promising ferroelectric material that stands out because of its high polarization and relatively low bandgap of about 1.5 eV, making it promising for optoelectronic applications based on visible-light absorption. While prior studies have explored the role of cation antisite defects and oxygen vacancies in modulating BFCO's properties - such as bandgap width, polarization switching bias, and imprint of the ferroelectric hysteresis loop-, the specific and controlled impact of Bi vacancies has remained largely unexplored.

This study demonstrates that the concentration of Bi vacancies in epitaxial BFCO thin films can be tuned by varying the deposition temperature during the growth process. We establish a direct correlation between the lack of Bi, the resulting p-type character, and the modified ferroelectric switching characteristics. For this purpose, we combine thin film growth with electrical characterization and density functional theory (DFT) calculations.

In extreme cases, the lack of Bi leads to nonmiscible, highly Bi-deficient phases with high conductivity. These phases prevent the establishment of an electric field across the film, thereby hindering polarization control.

The findings directly address the critical interface between defect chemistry, electronic transport, and functional ferroelectric properties in complex oxide thin films. We demonstrate how a fundamental growth parameter (temperature) allows to modulate the Bi concentration, which further impact the transport and polarization behaviour of the film. This insight is not only essential for the understanding of BFCO but also provides a critical guideline for designing and optimizing ferroelectric semiconductors for functional devices, such as photovoltaics, photodetectors, optoelectronics, non-volatile memory devices, where controlling conductivity and polarization switching is essential. Overall, the work highlights defect engineering as a powerful route for tuning multiferroic thin films for optoelectronic applications.



Reference: C. Hu, X. Henning, D. Stoeffler, L. Schlur, G. Versini, C.Leuvrey, F. Roulland, U-Chan Chung, T. Fix, A. Dinia, M. V. Rastei, and S. Colis, *ACS Appl. Electron. Mater.*, ***2026**, 8, 2364−2372*.
DOI : https://doi.org/10.1021/acsaelm.5c02590

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