Materials Radiations Structure
MRS

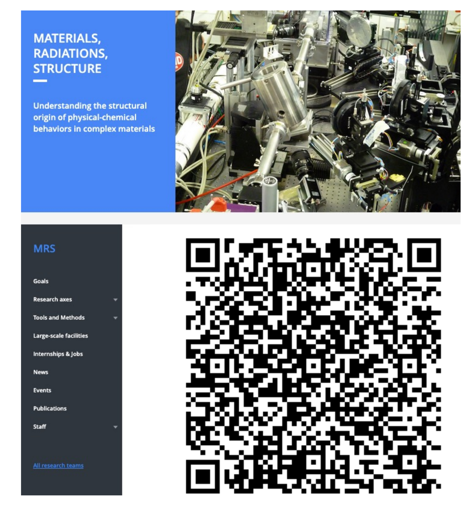
NÉEL institut

DESCRIPTION

The MRS team brings together chemists, geochemists, physicists, and crystallographers, united by a shared interest in revealing the structural, magnetic, and electronic configurations to elucidate the physical-chemical behaviours of materials. Our research involves all the material science steps and can take various routes, from several synthesis methods of novel materials, to a comprehensive characterization of their properties of interest, that includes extreme, *in situ* and *operando* conditions. We take advantage of a panel of cutting-edge and complementary techniques from all our disciplines, at the lab and at large scale facilities. We develop, adapt, and create new experimental methodologies so as to carry out our investigations from different points of view and in new fields.

2019 – 2024 *6 new members, 2 retirees*			
CNRS *sections 07 09 10 15 17 20*		***UGA*** *sections 28 33*	
18		*8*	
PhD students	***Post-doctoral researchers***	***Visitors***	***Trainees***
27	24	24	41

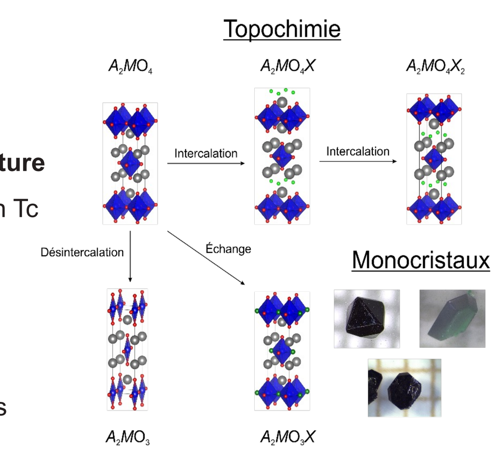
http://neel.cnrs.fr



RESEARCH AXES

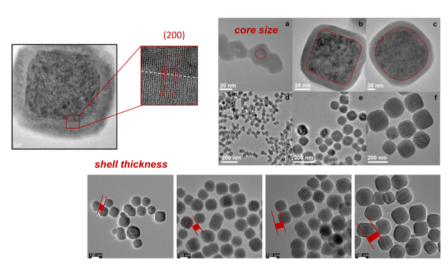
- **Synthesis**

  Our panel of techniques includes **ceramic** synthesis, **topochemistry**, **solution-based methods** (sol-gel, colloidal synthesis, soft chemistry, hydrothermal fluids), **vapor transport**, **mechanochemistry, high pressure-high temperature** synthesis, and **high entropy alloys**. Among all materials, we synthesize **molecular magnets**, **complex oxides**, high Tc **superconductors**, **multiferroics**, **electrolyte** and **electrode** materials in Li-ion batteries, H_2-storage materials.



- **Experimental methodologies**

  The team uses and develops complementary techniques at the laboratory and **in large-scale facilities** (X & neutrons sources). We have expertise in neutron, X-ray, and electron **crystallography**, while short range configurations are studied with **XAS** (X-ray Absorption Spectroscopy) and **Pair Distribution Function** (PDF). We use **Inelastic Scattering** (neutron, X-ray and Raman) to study materials' excitations. Multiscale and disordered materials are studied with **X-ray Photon Correlation Spectroscopy** (XPCS) and **tomography** combined with x-ray **ptychography** (being implemented with electrons). Nanostructures and electric field are imaged by **Transmission Electron Microscopy** (TEM).

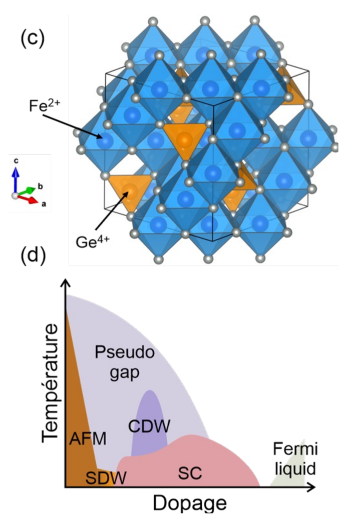


- **Nanostructures**

  We study semiconducting nanowires, particles of molecular-based magnetic solids whose size can be tuned down to a few tens of nanometers, epitaxial core-shell structures and strain-engineered systems in search of novel phases.

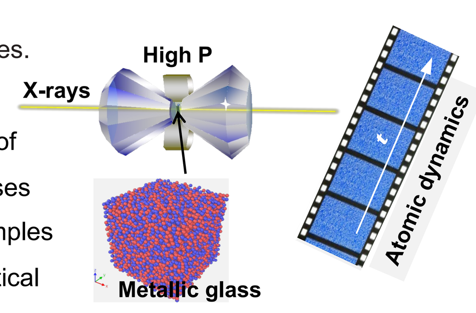
- **Quantum Materials**

  To elucidate the mechanisms of emergent quantum properties, we adopt an integrated approach, encompassing the **design of new phases**, their **synthesis**, and the **advanced characterization** of their structural and magnetoelectrical properties. We study **multiferroics**, which exhibit coexistence of magnetic and electrical orders intertwined through the so-called magnetoelectric coupling enabling the control of polarization (magnetization) via applied magnetic (electric) field. We realize unusual emergent properties by tuning phase transitions and magnetic orders with pressure, magnetic field, or chemical composition. Critical fluctuations can stabilize exotic states such as **nontrivial magnetic textures** or **unconventional superconductivity**. Macroscopic characterizations performed in the lab are complemented with state-of-the-art techniques at large-scale facilities, including XAS, (resonant) elastic and inelastic x-ray and neutron scattering.



- **Disordered, Heterogeneous and Multiscale Systems**

  Taking advantage of the extreme brilliance of the upgraded ESRF, we have developed a set-up to probe the atomic motion and structure in **metallic glasses** under hydrostatic compression, and investigated the dynamics and thermodynamic state of the material by combining PDF with XPCS and calorimetry measurements on densified glasses. Our long-standing commitment to the study of **cultural heritage materials** has led to the creation of *Patrimalp*, an interdisciplinary initiative where partners contribute different analyses of ancient artworks. We explore the materiality of these objects through physico-chemical techniques, primarily based on X-ray fluorescence and diffraction. Our analyses are conducted non invasively, either in situ using in-house portable instruments (**MbiFluo, *MobiDiff***), or on micro-samples at synchrotron facilities. To manage the vast datasets generated by these investigations, we develop and apply statistical and **machine learning**–based methods to gain insights into the objects' composition, history, and transformations.



- **Energy Materials**

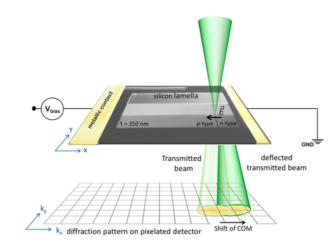
  Understanding and controlling order/disorder and microstructures in energy materials is crucial to optimizing their performance, whether through intrinsic atomic-scale disorder via doping or structural disorder emerging from nano-structuring during material processing. Multi-scale characterization is used to bridge the gap between atomic-scale insights and macroscopic performance by combining core spectroscopies and total scattering techniques, often performed in situ using custom-designed electrochemical and high-pressure cells. We investigate materials for **lithium-ion battery cathodes** and **hydrogen storage**. Our studies contribute to the broader goal of engineering next-generation materials for more efficient and sustainable energy storage solutions.

- **Hydrothermal fluids**

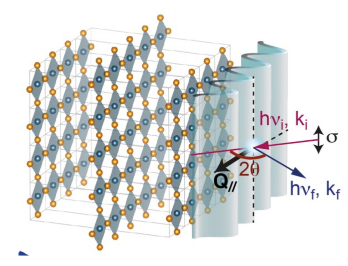
  We explore **Rare Earth Elements (REE) solubility** and speciation in hydrothermal fluids. This trend is driven by global geopolitical stakes and the strong need for European countries to regain their energetic independence. We use state-of-the-art FAME beamline at the ESRF to perform XAS measurements on diluted samples. The study of fluids/melts equilibria at very high temperature (<1000°C), in the geochemical context of subduction zones has been made possible by the development of updated in-house autoclaves.

TOOLS & METHODS

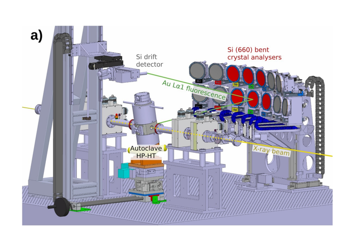
- **Synthesis equipments**
  - High pressure, high temperature, multizone ovens, lab-designed autoclaves for *in situ* studies
- **Transmission Electron microscopy**
  - JEOL TEM, 4D STEM, diffraction, imaging



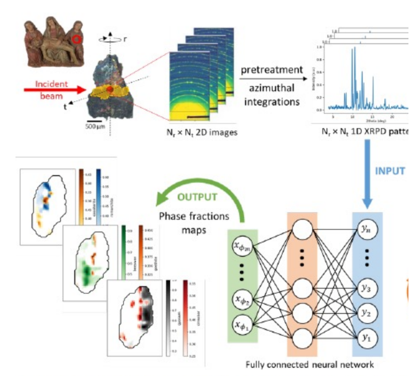
- **Differential Calorimeters**
- **High Pressure Cells**
  - Synthesis, diffraction, absorption
- **Scattering (x-rays, neutrons, electrons)**
  - Powder, single-crystal, High-resolution-high-flux diffractometers
  - Nuclear & magnetic scattering
  - MobiDiff : *in situ* fluorescence, diffraction



- **Ptychographic X-ray Computed Tomography**
- **X-ray Photon Correlation Spectroscopy**
- **Resonant Elastic & Inelastic X-ray Scattering**



- **X-ray Pair Distribution Function**
- **X-ray Absorption Spectroscopy**
- **Raman Spectrometers**



- **Dyna software**
  - X-ray Resonant Anisotropic & Magnetic Reflectivity
- **Management of ESRF/ILL French CRG beamlines**
  - ILL CRG-**D1B**
  - ESRF CRG-**FAME**, CRG-**FAME-UHD**, collaboration CRG-**D2AM**

ESRF · NEUTRONS FOR SOCIETY · FAME · FAME UHD · d2am

NEEL COLLABORATIONS

Research teams: **OPTIMA, MAGSUP, MNM, NPSC, QuantECA, Quant2m, SIN, SC2G, TMC, TPS**

Support groups**: AutoCarac, CRG, Cristaux Massifs, Cryogénie, Électronique, Ingénierie expérimentale, NanoFab, POM, SERAS, TEMA, X'Press.**

FINANCIAL SUPPORTS

- **ERC starting grants (2)**
- **ANR (13)**
- **IDEX UGA (1 CDP, 1 IRGA)**
- **PEPR H2 (1)**
- **MITI-CNRS (5)**
- **FEI – CNRS Physique (1)**
- **Procope projects with Germany (2)**
- **UGA LABEX (2), G-INP (2)**
- **MINCATEC**
- **AREVA Mines, Thales**
- **Universities Manchester, Orléans, King Abdullah, Rabat**
- **Fondation MAIF**

Distinctions :

- CNRS Bronze Medals : Martien Den Hertog (2019), Laura Chaix (2025)
- Prize of European Patent Office, Research category : Patricia de Rango (2023)

Conferences 2019-2024 :

- 24 Invitations to national and 29 to international conferences

Publications 2019-2024 :

- 468 articles, 9 theses, 1software

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