UNITÉ DE CATALYSE ET CHIMIE DU SOLIDE

Solid state chemistry

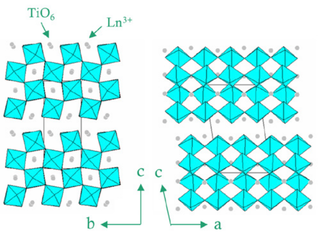
CMNM team: Thin films & nanomaterials

RESEARCH THEMES

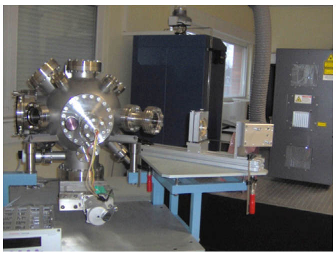
Thin films and nanomaterials with specific properties for integration in nanodevices

Our main objectives within the «Thin Films & Nanomaterials» team are to develop, synthesize, characterize and model new thin films and new nanomaterials for applications in the fields of nanoelectronics, optics and energy, focusing our efforts on lead-free piezoelectric oxides thin films and their integration into nanoelectromechanical systems. We study self-organized colloidal materials based on ferroelectric nanoparticles for terahertz applications as well as films that are dedicated to the storage of hydrogen.

Eco-friendly thin films and nanomaterials. In the context of environmental constraints, the use of substances deemed hazardous to health and environment, any integration of these into electronic components should be banned. In this respect, for the past several years, we have been interested in the synthesis, local characterization and modeling of new eco responsible thin films and nanomaterials along with evaluating their performances. In the particular framework of lead-free ferroelectric thin films, we are concerned with original phases, which we stabilize on suitable substrates. These are generally of complex composition. Mention may be made of the layered perovskite structure phases and frustrated pyrochlores of the general formula $A_2B_2O_7$ (A = lanthanide; B = Ti, Zr) or else those which belong to the A_2WO_6 system (A = lanthanide). Our concerns are directed towards their structural, microstructural and surface properties with the evaluation of local electromechanical properties as the main target. In mixtures of nematic liquid crystals and ferroelectric compounds, we diffuse size-and-concentration-controlled ferroelectric nanoparticles of $BaTiO_3$ and $Sn_2P_2S_6$. We measure their electrooptical properties, such as switch voltage and birefringence. In the framework of thin films dedicated to the storage of hydrogen, we give special attention to intermetallic phases based on nickel, magnesium, and even cobalt. When encouraging structures are predicted, these are grown in the form of thin films before their adsorption and desorption properties are considered and pulled-out.



High-performance tools for synthesis, local characterization and modeling. In order to carry out its research, the CMNM team owns a suitable range of techniques that allow for synthesis, characterization of the structure, the surface and physical properties at the macroscopic and local scale (at the nanometer level) as well as highly



TEAM LEADER FOREWORD


Rachel DESFEUX

Founded in January 2008, the "Thin Films & Nanomaterials" team consists in 9 solid-state chemists and physicists (including 1 emeritus). The team whole staff is from the University of Artois. Its activities are located at the Solid Chemical / Nanomaterials / Condensed Matter Physics interface. The team integrates skills in chemistry and solid-state physics (crystallography, molecular modeling, interactions with radiating-matter, optics, etc.) in a complementary and harmonious basis. These skills allow us to predict, characterize and measure the structural and physical properties of new (nano-) structures with specific properties that our team develops in thin films or nanoparticles with the ultimate aims and perspectives to integrating these into nanodevices dedicated to automotive, home automation, information storage or even telephony. These skills are also used to model, understand and explain electronic, electrical and magnetic mechanisms as well as the size effects that are involved in these new materials. All the work that our team carries-out, and devotes to, focuses on the world of «nano».


From left to right: above, Jean-François BLACH, Adlane SAYEDE and Jean-François HENNINOT; middle, Sébastien SAITZEK, Marc WARENGHEM and Anthony FERRI; bottom, Rachel DESFEUX, Belkacem MEZIANE and Marie-Hélène CHAMBRIER

KEY DATA

- **9** teachers-researchers (including **1** emeritus)
- **12** publications on average per year
- **2** book chapters over the 2013-2016 period
- **1** ANR contract, **1** BQRi over the 2013-2016 period

performing and adapted tools for detailed modeling. Accordingly, we grow oriented, textured and / or epitaxied thin films using chemically and physically routes through sol-gel techniques along with the use of pulsed laser deposition. In addition, the structural, microstructural and optical properties of our films are characterized by means of high-resolution X-ray diffraction (pole figures and reciprocal space maps recorded in collaboration with the MISPS team), Raman spectrometry, as well as ellipsometry. At the nanoscale level, we extract the local surface and physical properties (piezoelectricity, ferroelectricity, electron conduction, magnetism, etc.) through scanning probe microscopy, calling for the singular and particularly sophisticated modes that our microscopes are equipped with (AFM, MFM, EFM, PFM, ESM ...). We also predict and / or model the structural, electronic, electrical and magnetic properties of our samples, thanks to appropriate calculus and modeling tools (DFT, molecular modeling, etc.) that we have access to. These tools make it possible to highlight innovative structure-property-and-performance relationships.

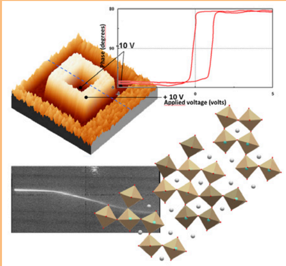
Towards new thin films materials with new performances and properties. The fast and continuous progress pertaining to innovative materials has led us to adapt our strategy and our research work towards responsive ways of approach. Along such prospects, new and inventive inquiries are being initiated with respect to i) original ionic-and-electronic mixed oxides thin films with electrochemical properties, ii) novel innovative multiferroic hybrid candidates, iii) composite materials that combine thin films of oxides and / or metal and polymers and whose ferroelectric or magneto-resistive performances are unusual, and iv) multilayers, for which light-energy conversion into electrical power, seems quite promising.

SOME HIGHLIGHTS AND RECENT TEAM PROJECTS/CONTRACTS

- Acquisition of a **novel scanning probe microscope** (MFP-3D from Asylum Research/Oxford Instruments) allowing access to low piezoelectric coefficients - Framework: CPER Materials Chemistry (Fédération Chevreul), 2014.

- Organization of an **«AFM Workshop»** at the Faculty of Sciences in Lens (France), 2015.
- **ANR-PNANO project – NANODIELLIPSO** (NANOparticles, DIELectric functions and ELLIPSOmetry) – UCCS/Horiba Jobin Yvon/INSP/CRPP, 2009-2012.
- **ANR project – NanoPiC** (Study of the multi-scale piezoelectric behavior of innovative micro- and nano-structured composites) – UMET/IEMN/ICGM/UCCS, 2016-2020.
- **Bonus International Quality Research (BQRi) – LAPEROX** (Implementation of layered perovskite oxides in photovoltaic cells) - University of Artois/University of Mons-Belgium, 2016.
- Contract associated with a **DGA/DSTL thesis funding** in Co-direction (France – UK), 2012-2016.

MAJOR PUBLICATIONS



Ferroelectric Control of Organic/ Ferromagnetic Spinterface
Advanced Materials, 2016, 28, 10204–10210 [IF=18,96] - doi: 10.1002/adma.201603638

Crystal structure and hydrogenation properties of Pd_5As *Dedicated to Prof. Bernd Harbrecht on the occasion of his 65th birthday,* Journal of Alloys and Compounds, 2016, 664, 256-265 [IF=3,014] - doi: 10.1016/j.jallcom.2015.12.039

Lead-Free α-La_2WO_6 Ferroelectric Thin Films
ACS Applied Materials & Interfaces, 2015, 7 (44), 24409–24418 [IF=6.813] - doi: 10.1021/acsami.5b01776

Refractive indices and birefringence of hybrid liquid crystal - nanoparticles composite materials in the terahertz region
AIP Advances, 2015, 5, 077143 [IF=1.496] - doi: 10.1063/1.4927392

Insight on the ferroelectric properties in a $(BiFeO_3)_2(SrTiO_3)_4$ superlattice from experiment and ab initio calculations
Applied Physics Letters, 2015, 107, 042904 [IF=3.293] - doi: 10.1063/1.4927600

RECENT BOOK CHAPTERS

Microstructure and nanoscale piezoelectric/ferroelectric properties in $Ln_2Ti_2O_7$ (Ln = lanthanide) thin films with layered perovskite structure
S. Saitzek et al., in Perovskites and Related Mixed Oxides: Concepts and Applications, 2015, Edition: 1st, Chapter 11, Wiley-VCH - doi: 10.1002/9783527686605.ch11

Evaluation of damages induced by Ga^+-focused ion beam in piezoelectric nanostructures
A. Ferri et al., in "FIB Nanostructures", Lecture Notes in Nanoscale Science and Technology, 2013, 20, 417-434, Springer - doi: 978-3-319-02874-3.

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