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One step closer to ultra-high magnetic storage density

The realization of two-dimensional crystals of magnetic nanoparticles with a period of a few nanometers is a kind of Grail that could pave the way for the storage of even more information on smaller areas. Over the years, researchers at the Modeling and Exploration of Metals (MEM) laboratory at the IRIG Institute and at the ESRF in Grenoble (BM32 line) have developed all the components and characterization techniques needed to progress in this direction.

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The growth of a graphene monolayer on iridium single crystals allowed them to synthesize a two-dimensional lattice of ***2.5 nm period***. The development of small-angle scattering and X-ray diffraction techniques (Figure 1) sensitive to nanometric material quantities has allowed these researchers to characterize the organization, size, shape and atomic structure of these lattices and nanoparticles.

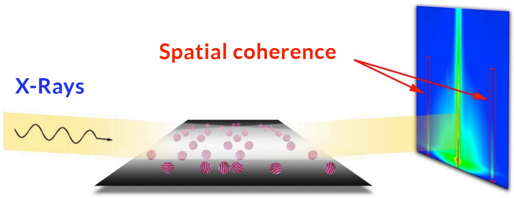

Figure 1. Synchrotron X-ray scattering at small angles in grazing incidence (GISAXS) that provides, on a two-dimensional detector, the Fourier transform (along a specific direction) of an assembly of nanoparticles (NP) on a substrate.

MEM researchers have ***collaborated*** with researchers at the Institut Lumière Matière in Lyon who are capable to produce iron-platinum nanoparticles which, by annealing, chemically organize themselves on an atomic scale and acquire magnetization. Then, they showed that not only do these particles organize themselves on the moiré lattice of graphene on iridium (Figure 2), but that they keep their magnetization (linked to their chemical order) and their supra-organization up to high temperatures, taking a further step towards a possible ultra-high magnetic storage density.

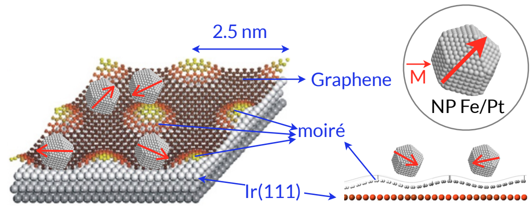

Figure 2. Organization of hard magnetic preformed FePt nanoparticles on the 2D lattice of graphene on Ir(111). There is a coincidence network of atomic sites every 10 Ir meshes and every 11 graphene meshes, generating a 2D network of periodic adsorption sites. Circle = magnetic nanoparticle.

REFERENCE

Capiod P, Bardotti L, Tamion A, Boisron O, Albin C, Dupuis V, Renaud G, Ohresser P and Tournus F. Elaboration of nanomagnet arrays: Organization and magnetic properties of mass-selected FePt nanoparticles deposited on epitaxially grown graphene on Ir(111). *Physical Review Letters*, 2019

2.5 nm period obtained thanks to the moiré (or interference) effect between the two lattices of different parameters.
This team is specialized in the development and "soft" deposition of preformed nanoparticles of very-well defined sizes (1 or 2 nm) and in their "soft" (or slow) deposition on surfaces.
Moiré: superposition of two crystalline networks with different periods.

Inside the protective shell of the measles virus genome

Measles virus is a highly contagious human pathogen that is currently on the rise in many countries, including France. The RNA genome of this virus is packaged (encapsulated) in helical molecular suprastructures, the nucleocapsids, consisting of thousands of nucleoproteins that bind to the entire genome of the virus. To spread in a cell, this virus uses a viral RNA polymerase. How does this polymerase access genetic material when it is protected by a capsid?

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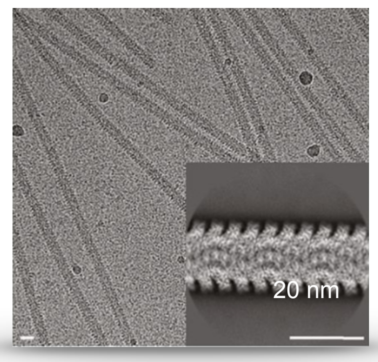
This is the task that IBS researchers have been working on. In a previous study[1], they had developed experimental methods to *in vitro* encapsulate a given RNA sequence They had thus demonstrated that they could trigger self-organization of measles virus nucleoproteins into nucleocapsids *in vitro* by addition of RNA. They thus provided a simple and versatile tool for studying the mechanisms and rates of assembly of nucleocapsids, and allowed them to detect a clear dependence on RNA sequence.

In this new study[2], they determine by cryo electron microscopy the three-dimensional high-resolution structure (3.3 Å) of these nucleocapsids. These structures reveal the positions and nature of the fine interactions between RNA and nucleoprotein. The identification of amino acids that are directly involved in encapsulation provides a better understanding of the stability of the superstructures, and their overall structure shows how the viral RNA polymerase is able to replicate the viral genome.

These new data could eventually lead to the development of new therapeutic strategies.

REFERENCES

[1] **Milles *et al.*** *Angewandte Chemie (Int Ed)*, 2016
[2] **Desfosses A, Milles S, Jensen MR, Guseva S, Colletier JP, Maurin D, Schoehn G, Gutsche I, Ruigrok RWH and Blackledge M.** Assembly and cryo-EM structures of RNA-specific measles virus nucleocapsids provide mechanistic insight into paramyxoviral replication. *Proceedings of the National Academy of Sciences USA*, 2019



High resolution image obtained by cryo electron microscopy of nucleocapsids. An average of these structures obtained by image analysis is also shown at the bottom left.

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At the heart of an intracellular symbiosis

The symbiosis between two living organisms requires a co-evolution of the two associated partners in a mutual benefit that eventually results in significant changes in their genome. Intracellular symbiosis is a particular form of symbiosis in which a living organism, such as a bacterium, survives and multiplies within the cells of its host. This type of symbiosis is widespread among invertebrates and highly contributes to insects' adaptation to their environment, including lack of some nutrients in the case of very specific diet. However, adjusting the number of endosymbiotes to a beneficial level and maintaining immune homeostasis in an organism chronically infected with mutualist bacteria is a major challenge for the host.

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Indeed, when an organism is infected by a pathogenic bacterium, the widely expressed immune receptors recognizing bacterial ***peptidoglycan*** or ***lipopolysaccharide*** induce an immediate inflammatory response to destroy the invaders. This response can be harmful to the body in the long term (which is also true for humans). In the case of endosymbiosis where an organism is chronically infected with mutualist bacteria, what are the mechanisms of bacteria tolerance?

Researchers from the IRIG's Large Scale Biology Laboratory, specialists in the immune response in fruit fly, participated in a study of INRA and INSA (Lyon) to understand the role of an evolutionary conserved peptidoglycan recognition protein (PGRP-LB) in the association between the cereal weevil (*Sitophilus zeamais*) and its bacterial endosymbiota (*Sodalis pierantonius*). This work shows that three different isoforms of the protein are differentially expressed depending on the context. An isoform is secreted and expressed in the insect's tissues only upon infection by pathogenic bacteria, while the two other isoforms (cytosolic and transmembrane) are permanently produced within the organ that hosts the endosymbiote: the bacterioma. In this bacterioma, PGRP-LB isoforms destroy peptidoglycans released by endosymbiotes, preventing chronic activation of the immune response and allowing endosymbiotes to survive while preserving the insect's health.

Cereal weevil (*Sitophilus zeamais*)
A set of Coleoptera insect pests that mainly attack cereals is called weevil. Some varieties also attack peas, hazelnuts, bananas, palm trees etc. It is thanks to its bacterioma that it can survive despite a poorly diversified diet.

Peptidoglycan is a component of the bacterial wall that maintains the shape of the cells and provides mechanical protection against osmotic pressure.
Lipopolysaccharides are molecules found in the outer membrane of Gram-negative bacteria.

REFERENCE

Maire J, Vincent-Monégat C, Balmand S, Vallier A, Hervé M, Masson F, Parisot N, Vigneron A, Anselme C, Perrin J, Orlans J, Rahioui I, Da Silva P, Fauvarque MO, Mengin-Lecreulx D, Zaidman-Rémy A, Heddi A. Weevil *pgrp-lb* prevents endosymbiont TCT dissemination and chronic host systemic immune activation. Proceedings of the National Academy of Sciences USA, 2019

The war of quantum coherence

A quantum computer is the meeting point of two very different fields of research. On the one hand, physicists who, over the past twenty years or so, have been able to control increasingly complex quantum states; this is the second quantum revolution. On the other hand, researchers in theoretical computing are imagining a new type of calculation that would exploit quantum mechanics to obtain performances unimaginable with existing computers. Today, a major effort is deployed to try to bring these two worlds together.

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Pheliqs
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The ***quantum bit*** that generalizes the 0 and 1 of our computers is a continuous object: it is described by a small needle that can point continuously between 0 and 1. The supposed power of quantum computers comes from a phenomenon called ***entanglement***: if a single needle is sufficient to describe a quantum bit, an exponential number 2^N is needed to describe the state of a machine with N quantum bits. Thus, the state of a machine with only 30 quantum bits is described by more than a billion small needles. This proliferation of degrees of freedom would make it possible to carry out massively parallel calculations.

But entanglement is also the nightmare of the quantum computer because it is necessary to be able to control precisely all these small needles while avoiding them to be disrupted by the other degrees of freedom present around them (vibration of atoms, fluctuations of the electromagnetic field...).

In an attempt to control this precision problem, theoretical computer researchers have envisioned "***quantum error correction codes***" where many quantum bits are used to form a single quantum metabit.

In recent work, Xavier Waintal, a researcher at IRIG's Quantum Photonics, Electronics and Engineering Laboratory, has examined these codes from the point of view of a physicist. His conclusions are rather pessimistic: he shows that a great many orders of magnitude stand between what we can achieve and what would be needed to envision building these quantum technologies.

REFERENCE

Waintal X. What determines the ultimate precision of a quantum computer? Physical Review A, 2019

In quantum computing, a ***quantum bit*** or qubit is the quantum state that represents the smallest unit of quantum information storage. A qubit memory differs significantly from a conventional memory in that one bit can only take the values 0 and 1, and only one at a time. A qubit does not have this restriction.
In quantum mechanics, ***quantum entanglement*** is a phenomenon in which two particles form a linked system and present quantum states that depend on each other regardless of the distance between them.
A ***quantum error correction*** (QEC) code uses several quantum bits to construct a "logical" quantum bit of better quality than the initial "physical" bit.

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Visit of Air Liquide

Helium 4, mainly obtained from natural gas fields, and helium 3, produced by the radioactive decay of tritium, are two gases commonly used in IRIG's Department of Low Temperature Systems (D-SBT) to obtain very low temperatures - helium 3 being the last gas to liquefy at around - 270°C. Beyond D-SBT, liquid helium 4 is used by a multitude of laboratories on the Grenoble's scientific polygon as well as by hospitals (NMR). D-SBT is thus able to produce 200,000 litres of liquid helium per year, which, combined with the capacities of the Institut Néel's liquefiers, make it possible to ensure this supply. Helium is a scarce resource that must be preserved and most of the experimental facilities on the scientific polygon are connected to a recovery network: the helium gas from the evaporation of the liquid is then compressed and stored under pressure before being liquefied again.

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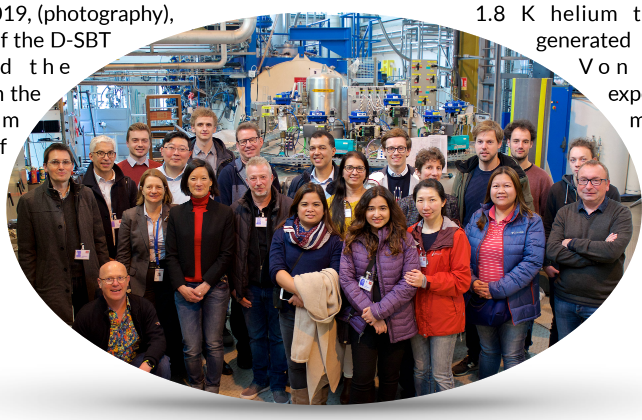
During the visit of the Air Liquide's Rare Gas and Helium Division on April 16, 2019, (photography), the various managers of the D-SBT laboratories had the opportunity to focus on the liquefaction of helium and the wide variety of its applications in science and more particularly those at D-SBT.

The technologies developed were thus exposed. Visitors were delighted to learn more about the use of helium (3 or 4) in cryo-refrigerators, to discover why cryogenics is necessary in space and how cooling is produced using technologies developed at D-SBT, such as pulse tubes, sorption coolers and adiabatic demagnetization refrigeration.



The helium sourcing and industrial directors, logistic coordinators, supply chain managers and maintenance technicians coming from France, the United Arab Emirates, China, the United States and the Netherlands during the visit on April 16, 2019, in front of HELIOS and the D-SBT helium liquefiers.
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The delegation was presented with the use of superfluid 1.8 K helium to study the vortices generated by the turbines of the Von Karman ***SHREK*** experiment installed in the multi-test cryostat of the 400W@1.8K station. In the same cryostat, the ***HELIOS*** experiment related to the ITER fusion reactor was also explained.
This visit was an opportunity to strengthen the partnership between Air Liquide and D-SBT in the context of projects in the sectors of space and large refrigeration. Since October 2018, these two partners have been indeed collaborating on technological developments within the framework of the Joint Laboratory between Air Liquide Advanced Technologies and the CEA.

SHREK: *Superfluid Helium high REynolds number von Kármán flow.*
HELIOS (*HElium Loop for hIgh lOads Smoothing*) is a supercritical helium loop developed to study the smoothing of variable thermal loads received by the cryogenic systems of future Japanese and ITER fusion reactors. HELIOS currently allows the characterization of the thermal coupling of samples of ITER superconducting magnets cooled by forced convection of supercritical Helium at 4.4 K and a pressure of 5 bar.

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