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Summary

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Editorial

This issue of ***IPCMS News*** is dedicated to some new exciting developments achieved in our institute. Controlled 40 nm sized magnetic nanoparticles have been synthesized to be used as contrast agents in medical applications; the mechanism for growing clusters on surfaces through the transport of atoms over large distances has been revealed; two-photon absorption has been used to record information on a submicron scale on rewritable materials; a model has been devised that allows the exploration of the decoherence time of a system of interacting particles that could be used as Q-bits; finally, a simple method to replicate non-uniform alignment patterns of nematic liquid crystals opens the way to new applications.

On the other hand, IPCMS further enhances its international basis. Along this line, our partnership with academic research centres in South Korea in the field of nanosciences has been strongly reinforced through the visit of IPCMS by a delegation of Hannam University on October 24, 2006 and the signature of a joint research proposal with EWHA Womans University, based in Daejon and Seoul respectively. Furthermore, IPCMS is one of the organizing institutions of the colloquium ***"Trends in Materials and Nanosciences"*** to be held in Strasbourg on November 21-24, 2006. This international meeting will focus on optics and plasmonics, nanostructured magnetic materials, molecular and self organized systems, biorelated materials, and on materials for energy.

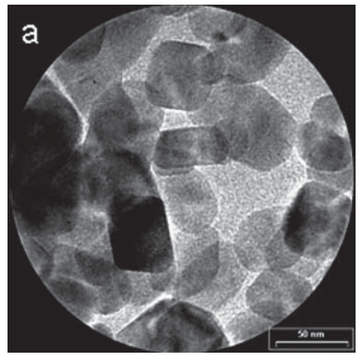
Marc Drillon
Director

ZOOM...ZOOM

***IPCMS** just ordered the first **JEOL JEM-2100F** transmission electronic microscope equipped with spherical aberration correction in France. It is specially designed for developing analytical 3D imaging.*

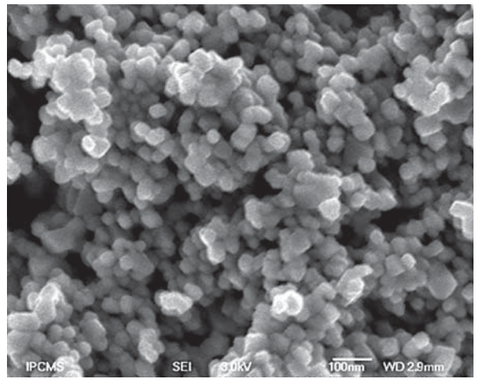
◆ Controlled size magnetic nanoparticles

The synthesis of magnetite nanoparticles with controlled size has long been of scientific and technological interest. Various synthetic methods have been reported in the literature for the preparation of nanoscale Fe_3O_4 particles with grain size lower than 20 nm, while many difficulties must be overcome to obtain monodisperse magnetite powders above 20 nm. Such sizes between 20 and 50 nm may be promising for biomedical applications (hyperthermia, contrast agent for NMR imaging...).



TEM image of magnetite nanoparticles.

We succeeded in synthesizing monodisperse magnetite particles of size around 39(±5) nm. They have been obtained by coprecipitation at 70°C of ferrous Fe^{2+} and ferric Fe^{3+} ions with $N(CH_3)_4OH$ followed by an hydrothermal treatment at 250°C. The lattice parameter a = 0.8393 ± 0.0002 nm and the Verwey transition at 120 K are characteristic of pure magnetite. XPS spectra display bands assigned to Fe^{3+} and Fe^{2+} showing that magnetite nanoparticles have no shell of maghemite at their surface. Chemical composition calculated from *Mössbauer spectra* leads to $Fe_{2.95}O_4$ with only a slight deviation from stoechiometry (δ ~0.05). Therefore, the nanoparticles consist of a stoechiometric magnetite core and a slightly oxidized outer layer. ■



SEM observations of the powder.

T. J. Daou, S. Bégin-Colin, G. Pourroy, J.M. Grenèche, C. Ulhaq-Bouillet, P. Legaré, C. Leuvrey, G. Rogez, Chem. Mat. 2006 **18** 4399-4404

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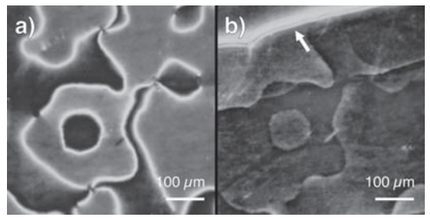
◆ Anchoring and Memory of the Azimuthal Nematic Orientation

We show that, contrarily to what is generally asserted, the azimuthal anchoring properties, strength and memory, of nematic liquid crystals on glass surfaces are intrinsically weak, but due to residual impurities that deposit onto the substrates, they may increase considerably, polymers being more efficient than small molecules. On using suitable polymers, the gliding of the easy axis that generally occurs when the nematic is submitted to a torque, may even become negligible.

Tests have been performed on adding to a nematic liquid crystal, 2 wt % of a monomer, a triacrylate, that we further polymerize by means of a convenient UV-irradiation. The nematic sample is prepared in such a way that several disclination lines run close to the substrates (Fig.a). Along these lines, the nematic orientation changes suddenly. With a UV-irradiation, we may then trigger the polymerization, and record the nematic orientation onto the plates. We demonstrate this property on separating the two plates of the cell and on building a new sample with one of the plates of the previous cell. The new sample reveals the orientation that has been recorded onto the plate of the former cell (Fig.b). This property could be interesting for applications, since it allows one to replicate non-uniform alignment patterns by means of a simple method, similar to imprinting. We may also deduce that it is not necessary to paint lubricating polymers onto the substrates to obtain weak azimuthal anchorings. It is just sufficient to work in clean conditions. ■



A complex orientation of a nematic liquid crystal (Fig.a) is recorded onto a substrate by means of a few nanometer-thick polymer film (Fig.b).

D. Pirès, Y. Galerne, Appl. Phys. Lett. **89**, 144110 (2006)

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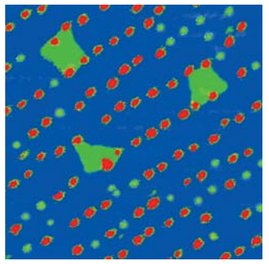
• Long range mass transport on surfaces: the atomic domino effect

It is generally believed that atoms move on surfaces by jumping from one adsorption site to another in a way similar to a ball in an egg box. In this case the distance between two sites (interatomic distance) is close to 0.3 nm. The new mechanism on the contrary implies a transport of atoms at large distances by means of a concerted motion (also called soliton) of several substrate atoms pushing each others (domino effect) in the topmost atomic layer.
In order to evidence this phenomenon, measurements were done in ultrahigh vacuum with a scanning tunnelling microscope (STM) on a gold single crystal that has been previously decorated with Co clusters (red). The approach exploits the property of deposited Co clusters to bury into the substrate upon thermal annealing. The atomic motion occurring when Co clusters are pressed into the substrate is then analysed. By repeating this experiment several times and with the help of numerical simulations of the atomic motions, it was possible to demonstrate that gold atoms are not ejected close to the sunken clusters but at distances as large as 70 nm from the initial perturbation, indicating a long range substrate mediated mass transport. Ejected gold atoms then accumulate into large islands separated by several 10 nm from each others.
The discovery of this long range mass transport is of great importance for the understanding of growth processes of crystals and thin films, for chemical reactions at surfaces as well as for processes where nanostructures form spontaneously as a result of self-organization. ■



False color STM image of the Co cluster network on Au(111) after annealing at 450 K. Small red patches represent the unaffected Co clusters. Small green patches are the sunken Co clusters. Large bright green patches are the rims formed by the displaced gold atoms.

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Phys. Rev. Lett. **96**, 076102 (2006).

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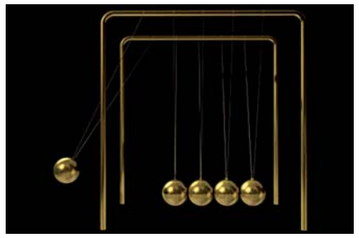
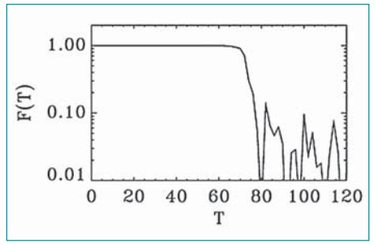


Principle of the domino effect, similar to the Newton pendulum.

• Time-reversal and decoherence in quantum devices

In a famous controversy with *Ludwig Boltzmann* at the dawn of modern statistical mechanics, *Joseph Loschmidt* pointed out that, if one reverses the velocities of all particles in a physical system, the latter would evolve back to its initial state, thus violating the second law of thermodynamics. The main objection to this line of reasoning is that velocity reversal is an extremely unstable operation and that tiny errors would quickly restore "normal" entropy increase. Nevertheless, time reversal is indeed possible, as was shown in spin echo experiments performed since the 1950s.

Loschmidt's idea has recently experienced a resurgence of interest in the context of quantum information theory. Indeed, any attempt at coding information using quantum bits is prone to failure if a small coupling to the environment destroys the unitary evolution of the wave function (decoherence). In order to estimate the robustness of a physical system, the following procedure has been suggested: a single quantum particle evolves under the action of a chaotic Hamiltonian H_0 until a time T; then, it is evolved backwards in time until $2T$ with the original Hamiltonian plus a small perturbation (the "environment"). The square of the scalar product of the initial and final states defines the ***Loschmidt echo*** or ***fidelity*** of the system. Theoretical and numerical studies showed that the Loschmidt echo decays exponentially with the time delay T.



What happens when one deals, not with a single particle, but with a large system of interacting particles, such as the electrons in a metallic or semiconductor nanostructure? In order to answer this question, we devised a quantum hydrodynamic model that includes electron-electron interactions via the elf-consistent Coulomb field. The results of our numerical experiments were intriguing: the fidelity does not decay exponentially, but rather stays close to unity until a critical time, after which it drops abruptly *(see figure)*. This unusual behaviour is related to the fact that the unperturbed Hamiltonian H_0 depends on the electron density n_e. When the perturbation induces a small change in n_e, H_0 is itself modified, which in turns affects n_e, and so on. Thanks to this "snowball effect", the perturbed and unperturbed solutions can diverge very fast. This effect could be a generic feature of interacting many-particle systems. If so, it would have an impact on the decoherence properties of solid-state quantum computation devices, which may then behave differently in the single-electron and many-electron regimes. ■

G. Manfredi, P.-A. Hervieux, *Loschmidt echo in a system of interacting electrons*, Phys. Rev. Lett. **97**, 190404 (2006).

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Collaboration Hannam University / IPCMS

A delegation of Hannam University (South Korea) has visited IPCMS on October 24, 2006. It included Prof. Kyu Hwan Yang (Vice-President of Hannam University), Prof. Kwang-Sup Lee (Department of Polymer Science and Engineering), Prof. In Seop Kim (Department of biology), Prof. Jong Sung Yu, Prof. Sung Ho Choi and Prof. Kuk Ro Yoon (Department of Chemistry). Most of the day has been devoted to short presentations of the activities of our Korean colleagues and of researchers of IPCMS, followed by fruitful discussions. Common interests have been revealed in several fields so that long term cooperative research proposals can now be developed.

Members of the Hannam University delegation with IPCMS researchers.

• Submicron rewritable optical storage in azobenzene copolymers

Polymeric materials doped with optical non linear molecules are intensively studied as interesting materials for image storage systems. In this field, the crucial parameter is spatial resolution. This need can be specifically addressed by the use of femtosecond laser sources, which, because of their high peak power, are able to give rise to multiphoton processes localized within a sub-wavelength volume in the vicinity of the focal point. We have used two optical quadratic processes, namely two photon absorption (TPA) and second harmonic generation (SHG), to locally respectively write and read information in voxels of less than 1μm^3 in volume.

The association of Disperse Red1 (DR1) to poly(methyl methacrylate) (PMMA), either as a host-guest system or in the grafted form of a copolymer, has been investigated intensively for well over a decade with the promise of applications in photonics. Because of its relatively good stability, it has become a model system in quadratic non-linear optics (NLO) of polymeric materials where it is essential to achieve at least a partial non centrosymmetric orientational order to get electro-optical activity and SHG capability.

We propose to encode optical information through the localized depoling of DR1 chromophores in thin films of grafted PMMA polymers with a femtosecond near IR laser source. This disorientation is promoted through the photoisomerization of the azo-dye component induced by a two-photon absorption process.

We start out with a sample where the chromophores have been oriented through a conventional corona poling method. Data writing consists by locally disorienting the polar order, using TPA isomerisation to randomize the initial orientation of the chromophores. Data retrieval are performed by monitoring SHG intensity while scanning the sample with a laser beam. In our approach, the information is being encoded into the succession of localized areas which have been disordered or not. This takes advantage of the fact that it is by far easier to induce disorder than to create order, and that the former is more irreversible.

Moreover, we have also demonstrated that this storage can be performed at such levels of intensities that the polymeric surface remains largely unaffected. This opens the way for a rewritable device since the film can be erased by repoling to recover its initial uniform SHG efficiency which can be used to store new data. ■

D. Gindre, A. Boeglin, A. Fort, L. Mager, K. D. Dorkenoo,
Optics Express, **14**, 9896 (2006).

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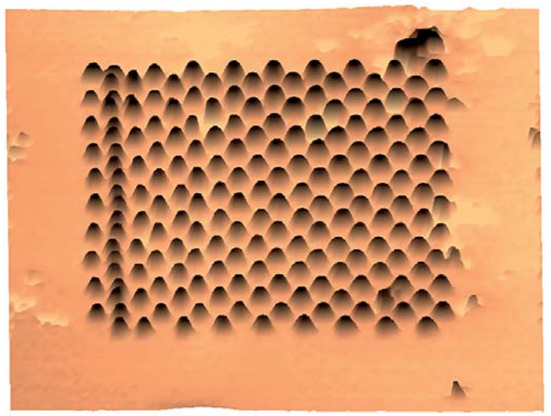

SHG patterned sample where the smallest distance between two adjacent points is about 2 μm.