EUROPEAN COMMISSION

Community Research

knowledge-based multifunctional materials and new production processes and devices

Self-organization and self-assembling
Expanding knowledge in site-dependent phenomena.

GSOMEN[1] is a Specific Targeted Research Project[2] funded by the EC which addresses the development of new materials (specifically, transition and noble metal nanoclusters) through a thorough understanding of the mechanism of their growth and supra-organization in 1D, 2D, 3D super-structures. The project also involves research on general features of the relationships between structure and properties of these materials. The aim is to achieve control over the size, size distribution, morphology, and hence on the properties of metal nanoparticles and supra-lattices.

Metal nanoclusters are self-assembled particles less than 10–100 nm in diameter. Two classes of metal nanoclusters have been selected as the object of GSOMEN:

- supported on oxide surfaces, as obtained by metavapor deposition under UHV
- coated by a layer of surfactants, as obtained in solution, and subsequently deposited an oxide surfaces.

These materials possess very appealing potential applications, which however still wait to be fully exploited because of the lack of knowledge, and hence lack of control, on their synthesis (the self-assembling and supra-organization processes). The aim of GSOMEN is to produce this knowledge by combining the most advanced techniques in the experimental synthesis and characterization with the theoretical simulation of the structure, growth and properties of metal nanoclusters. The recent advances in these fields, at the synthetical level (also through the use of external fields), at the characterization level (see, e.g., synchrotron-related techniques), at the simulation level (advances in computer hardware, development of acceleration techniques in the study of dynamical processes), if properly coordinated, make this goal feasible, thus allowing one to achieve control and orientation on the fabrication of these materials. Information on the basic metal-support, metal-ligand and nanoparticle-nanoparticle

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[1] "Growth and Supra-Organization of transition and noble MEtal Nanoclusters" (Contract Number : NMP4-CT-2004-001594)

[2] Specific Targeted Research Project : EU's instrument designed to generate new knowledge in a particular research topic with the aim of improving or developing new products, processes or services.

interactions is derived from the interplay of calibrated experiments and first-principle calculations, and is used to build up appropriate inter-particle potentials. These potentials are utilised in molecular dynamics and kinetic Monte Carlo simulations of the various growth processes under realistic conditions, from which a direct comparison with actual growth experiments is immediately possible. The concluding part of the project is also dedicated to the study of general structure/property relationships, to bridge the link with scientific and technological applications.

This three-year project has a total estimated budget of about € 3 million of which € 2 million is funded by the EU. It will be completed in September 2007.

Potential impact

The possible applications of (supra)-self-assemblies of transition and noble metal nanoclusters are diverse, and many of them are fascinating. Among these, interesting applications (some of which will be kept in mind in the investigation of structure-property relationships) are:

- quantum dots, of use in the miniaturization of electronic devices: the development of nanoscale single-electron transistors would increase the storage data capacity by a factor > 10^5
- magnetism: nanoscale ferromagnets to be used in the field of spintronics
- opto-electronic materials or linear wave-guides for the transport of electromagnetic energy
- chemical reactivity (sensors and catalysts): they are widely used in the modern car exhaust systems and as extremely sensitive gas sensors, and are proposed as a viable way to produce hydrogen from water
- polymer composites containing metal clusters with unusual optical, etc. properties
- biological labeling experiments: when coated with properly chosen organic materials, metal nanoclusters are proving very useful probes, due to their extreme sensitivity and low invasiveness, the latter related to the tiny quantity of matter to be introduced, and due to the possibility to chose the most bio-compatible metal elements and coatings among the possible ones

Socio-economic and policy objectives

Transition and noble metal nanoclusters can be environmentally friendly materials. With a proper choice of the type of metal and environment, the following advantages can be at hand: (a) the raw material is available at reasonable costs and without any foreseeable shortage for a long time; (b) as in most areas of nanotechnology, the consumption of the raw material in the production process is limited to the smallest possible amounts (limit of the miniaturization threshold); (c) the production processes are clean and the use of toxic substances can be minimized. For example, according to point (b) orders of magnitude “smart materials” with the same consumption of raw material as in conventional processes can be produced. This addresses the NMP objective of an eco-compatible and sustainable technology and production processes and development.

The EU strategies requiring efforts to promote gender equality and to provide information for and to foster dialogue with society have also been taken into account.

Work performed and results achieved so far

MgO, NiO, MnO/Pd(100) and SiO_2/Mo(110) thin films (ultra-thin in the case of MnO and SiO_2) have been synthesized, characterized and preparation protocols for them have been produced. The UHV deposition of Pd and Au clusters on regular MgO(100), of Fe and Au clusters on regular NiO(100) and of Pd clusters on ultra-thin SiO_2 films has been studied and the resulting nanoclusters have been characterized both experimentally and theoretically. Ag and Co nanocrystals with very low size dispersitivity have been prepared via the inverse-micelle route, and Pt and Au nanoclusters and nanopowders have been prepared (and characterized both experimentally and theoretically) via the solvated metal atom route using appropriate [DVS, $(CH_3)_2CO$] surfactants. The supra-organization of Ag nanocrystals into regular 2D hexagonal patterns or 3D fcc supralattices has also been obtained. All the results expected after the first year have been accomplished. The activity of the consortium will now concentrate on a more precise orientation of the synthetic procedures and control the corresponding nanocluster properties. The results have been published in a number of publications on high-impact scientific journals (the complete list is included in the project Web site). The synthesis, characterization and simulation protocols are available upon request to the scientific community.

Project Partners

The GSOMEN project represents a consortium of eight research centers and universities which pool expertise to achieve its objectives:

- ✓ IPCF - Consiglio Nazionale delle Ricerche, IT
- ✓ INFM - Consiglio Nazionale delle Ricerche, IT
- ✓ Université Pierre et Marie Curie, FR
- ✓ Centre National de la Recherce Scientifique, FR
- ✓ Commissariat à l' Energie Atomique, FR
- ✓ Universität Ulm, DE
- ✓ Max Planck Gesellschaft, DE
- ✓ Universität Graz, AT
- ✓ Technische Universität Münich, TUM

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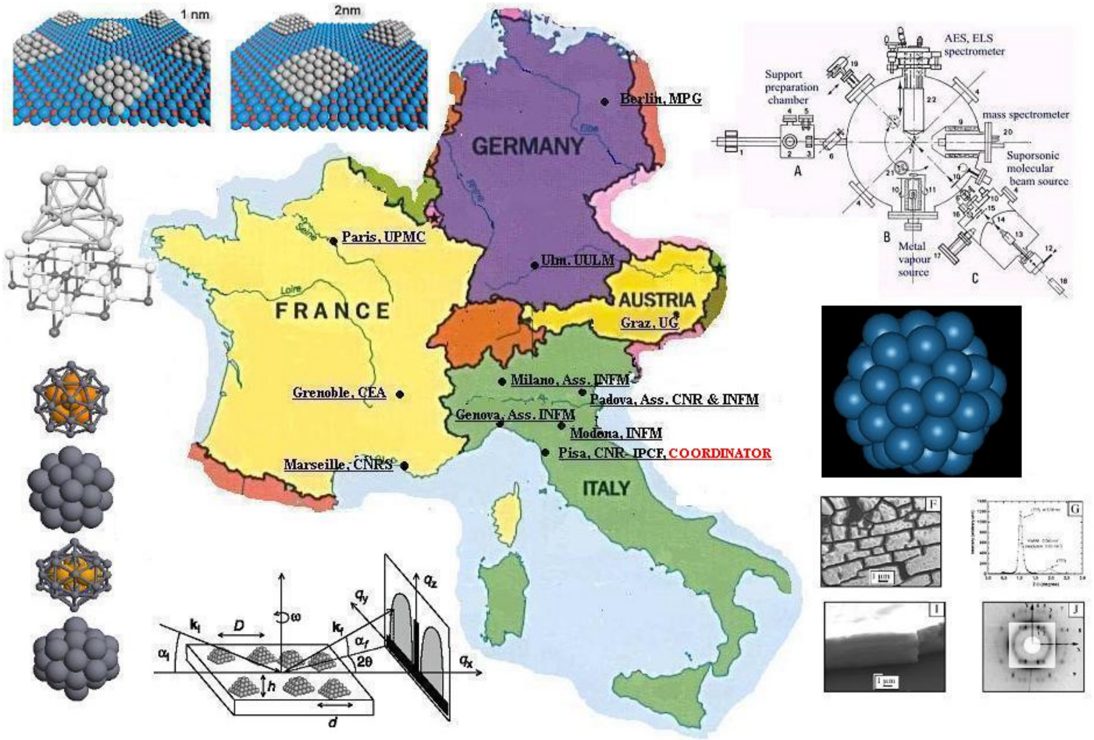
Project Web site

http://h2.ipcf.cnr.it/alex/gsomen.html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