



Name of the Plenary Speaker: Marie-Paule Pileni
Affiliation : Sorbonne Université, France

Short Biography.

Marie-Paule Pileni is Professor Emeritus at Sorbonne University, where she has spent most of her career. She was also a visiting researcher at EPFL in Lausanne and ETH Zurich in Switzerland and adjunct professor of chemistry and biochemistry at Georgia Tech in the United States. She has also developed major collaborations with the Fritz-Haber-Institut der Max-Planck-Gesellschaft in Germany, Chalmers University in Sweden and Canberra in Australia among others. She has chaired the Institut Universitaire de France, an institute that promotes cutting-edge research in France.

She pioneered the field of nanotechnologies where she achieved significant breakthroughs thanks to an extensive interdisciplinary approach, paving the way to new areas of research on a global scale. Over the last two decades, her major breakthroughs have been linked to 3D superlattices of nanocrystals known as colloidal crystals. These structures exhibit specific properties to both isolated nanocrystals and their assemblies. These hybrid structures have potential applications ranging from biomedicine to energy conversion such as solar energy or catalysis and are major factor in meeting the future needs of our societies.

She published more than 450 articles in peer journals and 3 books. Her Hirsch factor is 89 with 30,349 total citations. She received more than 22 world-class scientific awards and prizes from several countries (Japan, France, Germany, Netherlands, Spain, Sweden, United Kingdom, USA). She is member of five Academies among which the Swedish and European Academies. She is Grand officier de la Légion d'Honneur. Over her career, she promoted women in Sciences.

Title of the plenary lecture: A walk through 3D superlattices of nanocrystals

Abstract of the plenary lecture.

Here we focus on some unexpected properties linked to the self-assembly of nanocrystals into 3D superlattices, also known as colloidal crystals.

An analogy between atomic and colloidal crystals emerges. The atoms are replaced by (incompressible) nanocrystals and the atomic bonds by coating agents (carbon chains) that act like mechanical springs holding the nanocrystals together. The morphologies of nanocrystals, colloidal crystals and minerals are similar but are observed at different scales (from nm to mm).

This is also true for their crystal structures (fcc, bcc, hcp) as well as for negative crystals or quasicrystals. The difference in the scaling law makes it possible to observe, with colloidal crystals and minerals, intermediates in the crystal growth process that have been assumed for atomic crystals. This analogy has been extended to the vibration properties induced by light irradiation. In this way, the breathing mode and the coherent longitudinal acoustic phonon are observed in colloidal crystals.

The most surprising intrinsic property is the electronic transport through very thick colloidal crystals. In atomic crystals, this electronic transport is limited to a few nanometers in thickness. Electron transport through colloidal crystals up to 10 μm thick has been observed. In addition, Coulomb oscillations of the constituent elements take place, confirming the fingerprinting of nanocrystals in 3D superlattices. This behavior could be linked to coherent breathing within the colloidal crystals.

The experiments, described above, were carried out with self-assembled hydrophobic nanocrystals deposited on a substrate. Because of their specific properties, a fairly large number of applications could be expected if these assemblies could be dispersed in an aqueous solution.

To do this, we dispersed 3D superstructures of hydrophobic nanocrystals in an aqueous solution. This was achieved by covering the 3D nanocrystal superlattices with biomolecules capable of forming vesicles. This covering acts as a parachute to disperse the colloidal crystal. These 'clustered' superstructures subjected to light act as nano-heaters. Due to the dilution of the metallic phase, the penetration depth of visible light is much greater than that of homogeneous metallic nanoparticles of similar size. This results in a high overall average thermal load. Thus, the organic matrix (nanocrystal coating agents) acts as an internal reservoir for efficient energy accumulation in a few hundred picoseconds. Please note that these nano-heaters are not produced in dried systems.

Colloidosomes, a shell of one or more layers of hydrophobic nanocrystals, filled or not with colloidal crystals, have also been produced as well as spherical assemblies of nanocrystals called supraballs. These superstructures also behave like nano-heaters. This allows us to conclude that self-assemblies of hydrophobic nanocrystals dispersed in the aqueous solution behave as universal nano-heaters.

Colloidosomes and supraballs in contact with cancer cells increase the density of nanocrystals in lysosomes and near the lysosomal membrane. Importantly, their organizational structure is maintained in lysosomes, while the initially dispersed hydrophilic nanocrystals are randomly aggregated. As expected, inside cancer cells, these two structures act as nano-heaters and trigger local photothermal damage that is inaccessible to isolated nanocrystals and not predicted by global temperature measurements.