SORBONNE UNIVERSITÉ

CHINA SCHOLARSHIP COUNCIL

Appel à projets
Campagne 2022
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Title of the research project :

Advanced hierarchical superstructures of nanoparticles in liquid crystal matrices

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Research Unit

Name : Nano-Sciences Institute of Paris (INSP)

Code *(ex. UMR xxxx)* : UMR 7588

Doctorate School

Thesis supervisor’s doctorate school (candidate’s futur doctoral school) : Physics and Chemistry of Materials

PhD student currently supervised by the thesis supervisor (number, year of the first inscription) :

1 PHD student (2020)

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Description of the research project (*ENGLISH*)*:*

Ce texte sera diffusé en ligne : il ne doit pas excéder 3 pages et est écrit en interligne simple.
Ce texte est à l'adresse d'étudiantes et étudiants chinois, il doit donc être rédigé en anglais.

Détailler le contexte, l'objectif scientifique, la justification de l'approche scientifique ainsi que l'adéquation à l'initiative/l'Institut.

Le cas échéant, préciser le rôle de chaque encadrant ainsi que les compétences scientifiques apportées. Indiquer les publications/productions des encadrants en lien avec le projet.
Préciser le profil d'étudiant(e) recherché.

Merci d'enregistrer votre fichier au format PDF et de le nommer :
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Advanced hierarchical superstructures of nanoparticles in liquid crystal matrices

Introduction

It is known that liquid crystal topological defects trap nanoparticles in order to reduce the disorder energy associated with the defect cores [1]. In our group, we have demonstrated that an array of liquid crystal topological defects can be used to confine nanoparticles, leading to the formation of original networks of nanoparticles [2-7]. In the so-called smectic oily streaks made of an array of 1D dislocations and 2D grain boundaries [8], these are nanoparticle chains [2-6] and 2D nanoparticle networks that have been demonstrated to be hexagonal networks if nano-spheres are concerned [7]. Both nanoparticle chains and 2D nanoparticle networks appear to be strictly oriented along a single well-defined direction which is usually particularly difficult to achieve with other methods.

The PHD project will consist in using these new organizations of nanoparticles in order to pursue two parallel goals:

1. **Allowing for the study of specific interactions between nanoparticles of different nature**.

   They will be metallic nanoparticles characterized by a resonant light absorption at a specific wavelength, the so called plasmonic resonance (LSPR). LSPR is controlled by the nature and the shape/size of the nanoparticles, but also by the orientation of the nanoparticles, allowing for a control of plasmonic light absorption by light polarization. In the nanoparticle networks confined in liquid crystal defects, the metallic nanoparticles (in particular gold nanoparticles) will be brought in close vicinity of semi-conducting nanoparticles able to emit light (quantum dots - QDs). This will induce a Purcell effect in relation with the electromagnetic coupling between the two kinds of nanoparticles. The PHD student then will study the Purcell effect as a function of nanoparticles shape and size. This will allow for a deep understanding of this complex phenomenon but also will allow for the evidence of Purcell effect controlled by light polarization, which, to the best of our knowledge, has still never been evidenced.
2. **Creating activated networks of nanoparticles.**

   The PHD student will take advantage of the liquid crystal matrix that is easily activated by external fields. This concerns in particular temperature, the smectic/nematic transition occurring at 33.5°C or electric field. This second goal will thus be shared into two parts

   1) An electric field will be applied to rotate the liquid crystal molecules close to the substrate and thus to rotate the topological defects. This will induce a rotation of the nanoparticle organizations leading to a modification of the nanoparticle optical properties. It concerns in particular the anisotropy of optical properties for a control of optical properties in presence of polarized light. An activation induced by electric field will thus be obtained for both kind of nanoparticles,

metallic ones with plasmonic properties [2-3, 5-6] and QDs when nano-rods are used [4].

2) Magnetic nanoparticles will be inserted in the nanoparticle organizations made of metallic nanoparticles or of QDs or of a mixture of both. Oscillating magnetic field will be applied. Hyperthermia is thus expected, associated with a local heating around the magnetic nanoparticles. This heating will locally increase the disordered core of the liquid crystal topological defects and will consequently locally modify the structure of the nanoparticle organizations and the related optical properties.

Reference:

[1] Blanc C., Coursault D. and Lacaze E. *Liq. Cryst. Rev.* **1** (2013) 83-109.
[2] Coursault D., Grand J., Zappone B., Ayeb H., Lévi G., Felidj N. and Lacaze E. *Adv. Mat.* **24** (2012) 1461-1465.
[3] Coursault D., Blach J. F., Grand J., Coati A., Vlad A., Zappone, B., Babonneau D., Lévi G., Felidj N., Donnio B., Gallani J-L., Alba M., Garreau Y., Borensztein Y., Goldmann M. and Lacaze E. *ACS Nano* **9** (2015) 11678-11689.
[4] Pelliser L., Manceau M., Lethiec C., Coursault, D., Vezzoli S., Lemenager G., Coolen L., DeVittorio M., Pisanello F., Carbone L., Maitre A., Bramati A. and Lacaze E. *Adv. Funct. Mat.* **25** (2015) 1719-1726.
[5] Rozic B., Fresnais J., Molinaro C., Calixte J., Umadevi S., Lau-Truong S., Felidj N., Kraus T., Charra F., Dupuis V., Hegmann T., Fiorini-Debuisschert C., Gallas B., Croset B. and Lacaze E. *ACS Nano* **11** (2017) 6728-6738.
[6] Do S.-P., Missaoui A., Coati A., Coursault D., Jeridi H., Resta A., Goubet N., Royer S., Guida G., Briand E., Lhuillier E., Garreau Y., Babonneau D., Goldmann M., Constantin D., Gallas B., Croset B. and Lacaze E. *Front. Phys.* **7** (2020) 234.
[7] Do S.-P., Missaoui A., Coati A., Resta A., Goubet N., Wojcik M. M., Choux A., Royer S, Briand E., Donnio B., Gallani J-L., Pansu B., Lhuillier E., Garreau Y., Babonneau D., Goldmann M., Constantin D., Croset B., Gallas B. and Lacaze E. *Nano Letters* **20** (2020), 1598-1606.
[8] Coursault, D., Zappone, B., Coati, A., Boulaoued A., Pelliser L., Limagne D., Boudet N., Haj Ibrahim B., de Martino A., Alba M., Goldmann M., Garreau Y., Gallas B. and Lacaze E. *Soft Matter* **12** (2016) 678-688.

Expected objectives and research methods:

Scientific objectives:

- Preparing mixtures of nanoparticles confined into 1D or 2D liquid crystal topological defects.
- Studying the nanoparticle structure in the mixture
- Demonstrating the effect of electromagnetic coupling between nanoparticles

confined in the liquid crystal topological defects on their optical properties.

- Studying the influence of nanoparticle size and shape on these optical properties
- Building the set-up allowing to apply a lateral electric field.
- Building the set-up able to apply oscillating magnetic fields in collaboration with our colleagues from the laboratory Phenix, specialist of magnetic colloids.
- Measuring the variation of nanoparticles structures and the variation of optical properties when the electric field or the oscillating magnetic field is either switched on or switched off.

Methods:

- ➢ Morphological characterization of the liquid crystal structure by Polarized Optical Microscopy and X- ray Scattering under Synchrotron Facilities.
- ➢ Morphological characterization of nanoparticle structures via atomic force microscopy (AFM) and scanning transmission electron microscopy (STEM).
- ➢ Crystalline structure of nanoparticle structures by X- ray Scattering under Synchrotron Facilities.
- ➢ Optical properties of nanoparticles by UV-visible spectroscopy and fluorescence microscopy and spectroscopy.

Necessary skills of the PHD student

The subject is largely experimental requiring a real interest of the PHD student for experimental measurements, in particular for combination of a large number of experimental measurements, including measurements at large scale facilities like synchrotron facilities.

We plan also to interpret our results with theoretical models.

A good knowledge on condensed matter physics and physico-chemistry will thus be appreciated.