AAP China Scholarship Council - CSC 2023

PROJET DE RECHERCHE DOCTORALE (PRD)

Titre du PRD : Advanced hierarchical superstructures of nanoparticles in liquid crystal matrices

DIRECTION de THESE

Porteuse ou porteur du projet (***doit être titulaire de l'HDR***) :

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Unité de recherche : Code (ex. UMR xxx) et Intitulé : UMR7588 (INSP)

Ecole doctorale de rattachement : ED397 - Physique et Chimie des Matériaux

Nombre de doctorants actuellement encadrés : 3

CO-DIRECTION de THESE (HDR) ou CO-ENCADREMENT (Non HDR) :

NOM :

Prénom :

Titre : Sélectionner ou Autre :

Section CNU :

Email :

Unité de recherche : Code (ex. UMR xxx) et Intitulé :

Ecole doctorale de rattachement : Sélectionner

Nombre de doctorants actuellement encadrés :

CO-TUTELLE INTERNATIONALE envisagée : ☐ OUI ☒ NON

DESCRIPTIF du PRD :

*Ce texte sera affiché en ligne à destination des candidates et candidats chinois : il ne doit pas excéder **2 pages** doit être rédigé en **ANGLAIS***

Advanced hierarchical superstructures of nanoparticles in liquid crystal matrices

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 [2-8]. In the so-called smectic oily streaks made of an array of 1D dislocations and 2D grain boundaries [9], these are nanoparticle chains [2-6] and 2D nanoparticle networks. These latter ones have been demonstrated to be hexagonal networks if nano-spheres are concerned [7-8]. 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 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 in presence of polarized light. An activation induced by electric field will be obtained for both kind of nanoparticles, metallic ones with plasmonic properties [2-3, 5-8] and QDs when nano-rods are used [4, 8].

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] Jeridi H., Niyonzima J. de D., Sakr C., Missaoui A., Shahini S., Vlad A., Coati A., Goubet N., Royer S ., Vickridge I., Goldmann M., Constantin D., Garreau Y., Babonneau D., Croset B., Gallas B., Lhuillier E. and Lacaze E. Soft Matter 18 (2022) 4792-4802.

[9] 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.

Knowledge on condensed matter physics and physico-chemistry will be appreciated.

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