Electrostatically driven combinatorial directed assembly of colloidal nanoparticles assisted by microfluidics

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KEY WORDS: Nanotechnologies, Directed assembly, Colloidal Nano-objects, Nanoxerography, Combinatorial assemblies, Microfluidics,

Introduction and context – The study of the original properties of colloidal nanoparticles synthesized by chemical means and their integration to realize the active area of functional devices require their directed assembly on specific areas of solid or flexible surfaces. For more than a decade, the *Nanotech* team of the Laboratory of Physics and Chemistry of Nano-Objects (LPCNO- UMR 5215 INSA-CNRS-UPS) at Toulouse, Fr has developed an innovative two steps technique called nanoxerography, which can tackle this challenge. This process consists first in injecting, in an electret material, electrostatic charges in the shape of patterns of desired geometries (cf. injection step in the **Fig.1a** below). The obtained charged patterns are then used as trapping sites to assemble electrostatically on the surface, charged or polarized nano-objects initially dispersed in solution (*cf.* figure below). For now, charge injecting techniques like using a polarized Atomic Force Microscopy (AFM) tip [1], electrical microcontat printing [2] or electrical nanoimprint lithography [3], mastered in the team, were employed in a complementary manner depending on applications to address either very local hundreds of nm² regions or surfaces of tens of cm².

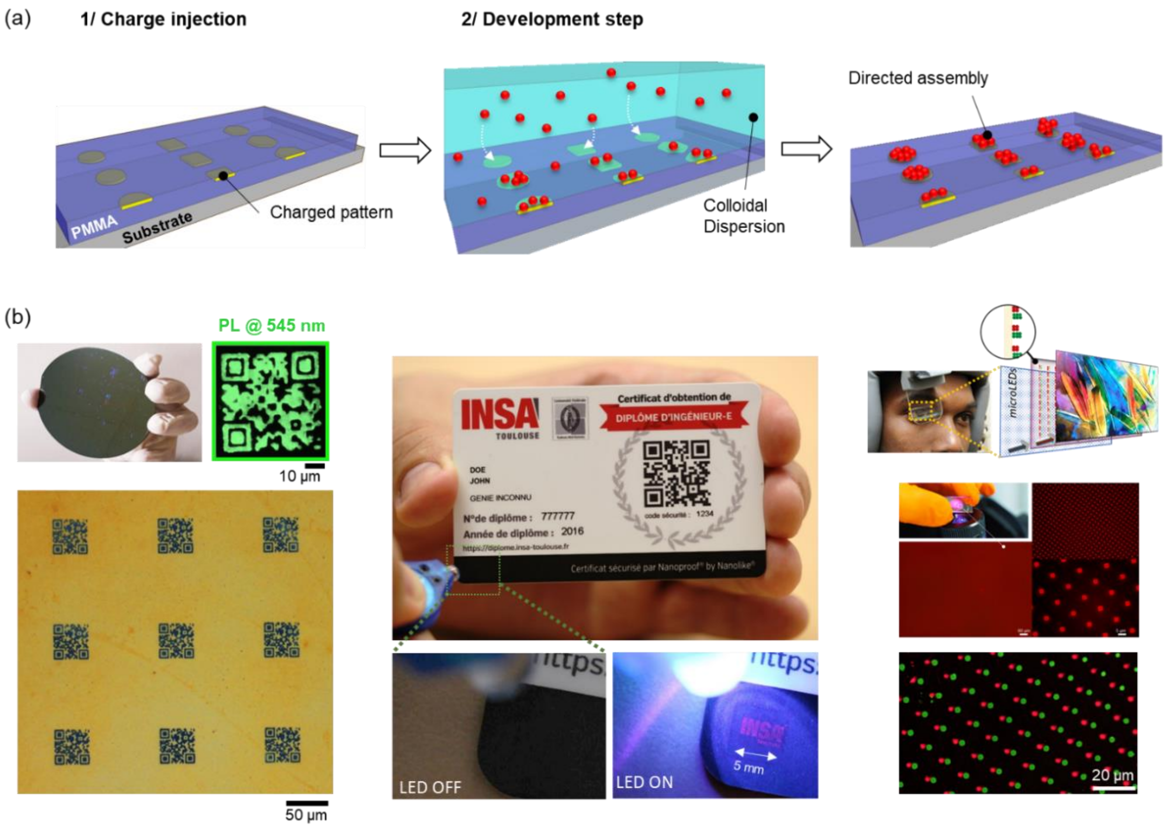

Fig.1 a) Nanoxerography two step protocol b) Examples of single directed assemblies by nanoxerography for anticounterfeiting and combinatorial ones for micropixels in microdisplays.

During previous studies, the *Nanotech* team has demonstrated that nano-object assemblies of controlled density [4], single or binary (combining two types of nanoparticles) [5] could be fabricated in 2D and even in 3D with certain kinds of systems [6]. And various applications have been targeted like fabricating red and green emitting micropixels in micro-displays for Virtual Reality/Augmented Realty devices [7] or microtags for secured tracking of products and anticounterfeinting [8] (cf. **Fig.1b**). The goal of this PhD subject will be to keep exploring the potentialities of nanoxerography while working on both the charge injection and development steps and enlarging the range of functional applications.

Subject – The proposed work is mainly structured around two research axes:

(i) Stamp/mold less charge injection process

The candidate will be in charge of investigating new approaches to induce charge injection on electret surfaces but without the need of a conductive stamp or mold acting as an injection contact electrode. For that, the idea will be to set up a protocol and associated recipes based on an equipment recently purchased dedicated to Digital Micromirors Devices maskless UV photolithography (**Fig.2**). Such photo induced charging effects have never been explored before and the candidate will be leading their complete investigation.

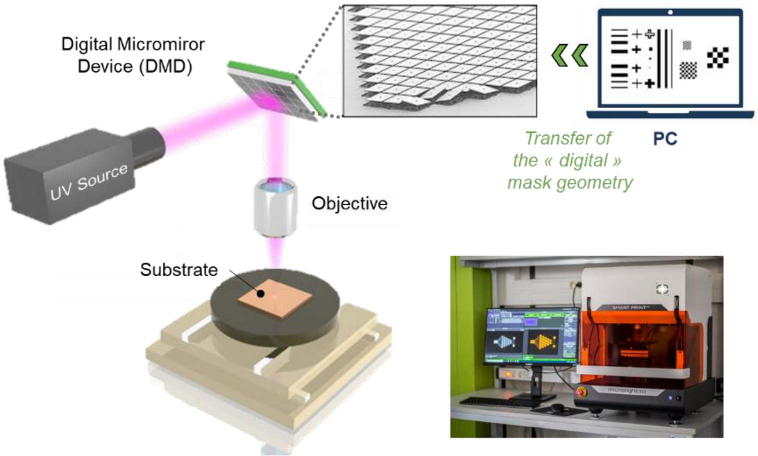

Fig.2 Concept of DMD UV photolithography and corresponding equipment from Microlight3D

(ii) Simultaneous combinatorial assemblies via microfluidics tools

The candidate will benefit from the environment of a microfluidic platform we recently built in the clean room of the *Nanotech* team. It includes tools to fabricate reversible multifunction microfluidic chips following protocol we patented [9], reversed optical microscope with high-speed camera, programmable equipments and switchs to automatize dispersion injections in chips. The idea is to benefit from a phenomenon that appear in microfluidic channels, *i.e.* creation of laminar flows, to address simultaneously different charged areas with different colloidal dispersions, thus leading to combinatorial assemblies in a single development step (**Fig.3a**). With the first preliminary experiments, we also have observed a new effect of nano-object directed diffusion guided by electric field, that the candidate will characterize and study (**Fig.3b**). Based on such multiple combinatorial assemblies, we aim to target applications in multiplexed sensing (**Fig.3c**).

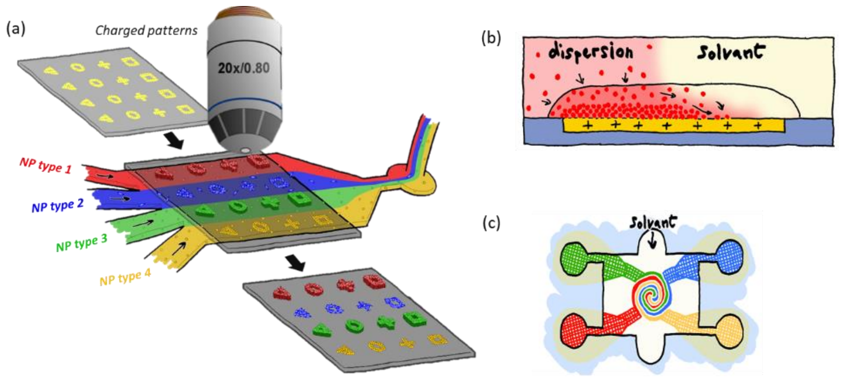

Fig.3 a) Concept of simultaneous combinatorial directed assembly b) New electrostatically driven diffusion phenomena c) Illustration of multiplexed sensing

Required Profile – Master Degree or French Engineer School Diploma in Solid State Physics, Nanotechnologies, Microfluidics, Colloids. The PhD candidate will integrate the *Nanotech* team of LPCNO in Toulouse where he/she will be trained on atomic force microscopes, microfluidics and micro/nanofabrication techniques linked with the nanoxerography method. The PhD candidate will have to be interested in experimental work which will mainly occur in the clean room of the team. We are looking for a dynamic student who will show scientific rigor and curiosity to complete successfully this project.

Contact – Interested in this offer? Please feel free to contact Dr. Etienne Palleau and Prof. Laurence Ressier and
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References - [1] Palleau *et al, ACS Nano*, (2011) ; [2] Poirot *et al, ACS App. Nano. Mat.* (2018) ; [3] Ressier *et al, Nanotechnology* (2012) [4] Ressier *et al, IEEE T Nanotech.*, (2009) ; [5] Palleau and Ressier *Adv. Mater.* (2018) [6] Sangeetha *et al*, *Nanoscale*, (2013) [7] Yassitepe *et al, ACS App. Nano. Mat.* (2024) [8] Platel *et al, JCIS* (2020) [9] Raffy et al, *ACS Appl. Polym* (2021)