3D Capillary Force Assembly: Fabrication of white light emitters

J.Cordeiro, O. Lecarme, G. O. Dias and D. Peyrade*
CNRS-LTM-UJF, CEA-LETI 17 Av. des Martyrs 38054 Grenoble France

Keywords: Colloids, 3D Assembly, Fluorescent particles, White light

Due to their high optical confinement[1] and high photostability, fluorescent nanoparticles are potential candidates for light emitters[2]. Moreover, because of the large variety of dye-doped nanospheres, they can be very attractive for the elaboration of white light emitters[3]. In this work, we exploite the Capillary Force Assembly (CFA) technology[4,5] to build three-dimensional (3D) deterministic Particles Superstructures (PS) that emit white light in a fast and flexible fabrication process. We also study the white light emission performances such as purity of the "white" light and emission lifetime of the PS.

The fabrication of the white light emitters first consists in preparing a colloidal suspension by mixing red, green and blue (R:G:B) fluorescent 100 nm polystyrene microspheres with a predetermined ratio (**Fig. 1a**). This solution is then used for the CFA step on a patterned sample previously fabricated by replicating Polydimethylsiloxane (PDMS) on a silicon mold (**Fig. 1b**). After assembly, the 3D superstructures are transferred on a blank silicon substrate with the help of a micro-contact printing technique[6]. Thanks to this process, 1 µm height wide 3D objects with a crystalline arrangement (**Fig. 2**) were built (~ 12000 particles of diameter 100 nm).

Optical characterization of the PS under UV light excitation (365 nm) is then performed with a microspectroscopy set-up. Fluorescence spectra of the PS were measured and compared to those of each R:G:B particles solution. For a R:G:B ratio of 13:10:6, spectra cover the whole visible spectral range induced by a right combination of the 3 types of doped particles (**Fig. 3a**). This physiological white is characterised by its (x;y) coordinates on the CIE1931 chromaticity diagram. We obtain coordinates of (x;y) = (0.37;0.34), very close to a "pure" white (x;y) = (0.33;0.33). Homogeneity of the white light emission on the same PS is also observed (**Fig. 3b**).

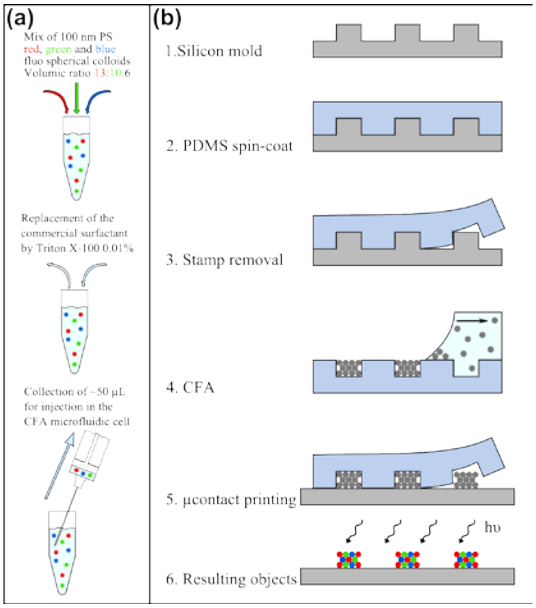
Finally, we demonstrate that it is possible to modify PS in terms of shape (triangle, square, star) and size (2 to 4 µm) (**Fig. 4a,b,c**) thanks to CFA. Due to the nature of the dyes (fluorescent molecules embedded in a polystyrene matrix), these white light emitters show a photostability (**Fig. 4d**) over the time (more than 50 mn).

This presentation will highlight the CFA technology to create 3D particule superstructures. The performances of the white light emitters will be discussed. The application for integrated optics in the visible spectrum range will be proposed.

---

* To whom correspondence should be addressed. E-mail: david.peyrade@cea.fr

[1] A. Darafsheh et al. Optics Express, 3440 19- 4 (2011)
[2] L. Wang et al., Nano Lett., 84(6), 2006.
[3] K. N. Hui et al., Nanotechnology, 355203(19), 2008.
[4] T. Pinedo et al., Microelec. Eng., 1089(86), (2009)- T. Pinedo et al., JVST B, 2513(26) (2008).
[5] O. Lecarme et al., Appl. Phys. Lett., 083122(98) (2011)- O. Lecarme et al., JVST B, C6011(28) (2010).
[6] T.Kraus et al., Adv. Mater., 2438(17) 2005.



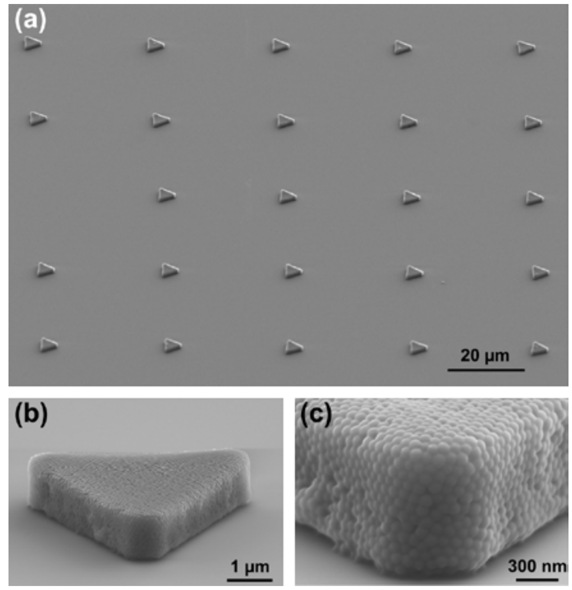
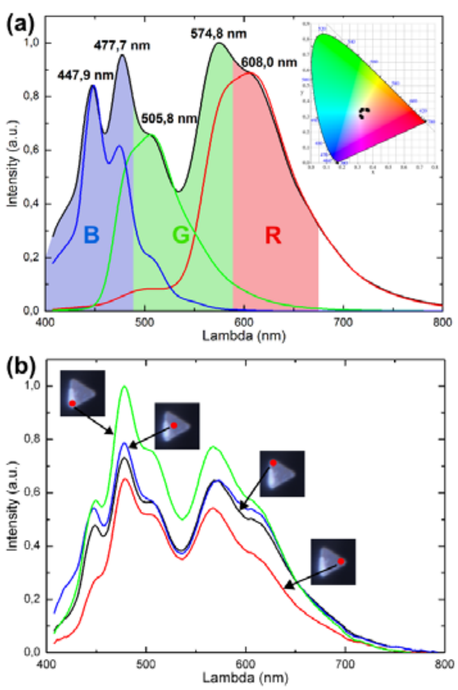


Figure 1. *Fabrication process*: **(a)** Preparation of the colloidal suspension. **(b)** Spin-coat of a PDMS layer on a silicon mold, use of the stamp as template for the CFA and micro-contact printing step.

Figure 2. *SEM micrographs of transferred 3D colloidal microstructures.* **(a)** Large scale view of an array of triangular Particles Structures (PS). **(b)** Zoom on a single object. **(c)** Details of the crystalline arrangement.



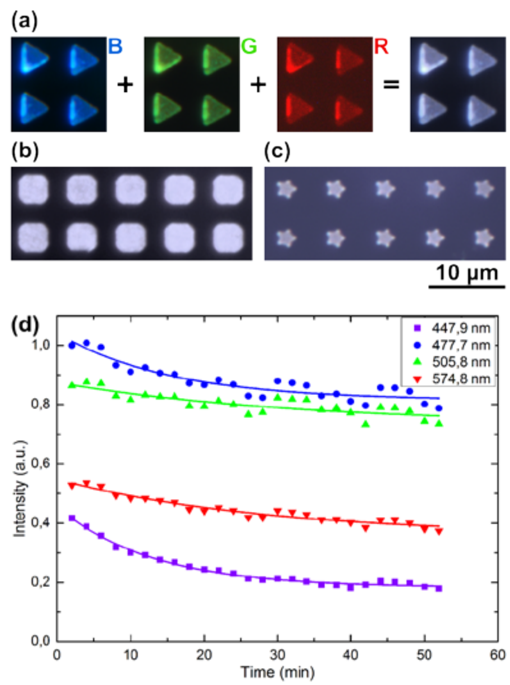


Figure 3. **(a)** Normalized fluorescence spectra of a PS consisting of a 13:10:6 R:G:B ratio and comparison with the encapsulated individual dyes. Corresponding (x;y) coordinates on a CIE1931 chromaticity diagram (inset). **(b)** Fluorescence spectra homogeneity study on a PS.

Figure 4. Fluorescence micrographs of white light emitters resulting of R:G:B dyes contribution **(a)** for different shapes and sizes **(b)**, **(c)**. **(d)** Photobleaching curve for the 447.9, 477.7, 505.8 and 574.8 nm fluorescence peaks.