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To cite this article: I Elvira *et al* 2017 *J. Phys.: Conf. Ser.* **867** 012019

IOP Conf. Series: Journal of Physics: Conf. Series **867** (2017) 012019 doi:10.1088/1742-6596/867/1/012019

Orientation and patterning of zeolite micro-crystals on photorefractive templates

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Abstract: Evanescent fields photo-generated on the surface of photorefractive Fe-doped $LiNbO_3$ templates have been used to trap and align anisotropic zeolite micro-cylinders. *x*- and *z*-cut crystal configurations have been employed to obtain different 1D and 2D zeolite micro-patterns. Inside of the patterns, a substructure of zeolites aligned along the electric field, either parallel or perpendicular to the surface, have been obtained. The experiments have been analyzed to the light of a theoretical analysis that satisfactorily explains the main experimental features.

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1. Introduction

The photovoltaic tweezers (PVT) technique [1] takes advantage of the photorefractive (PR) effect presented in some ferroelectric crystals to efficiently trap and arrange different kind of objects. However, alignment of anisotropic objects with PVT has not been investigated in deep so far. Only a previous work mentioning orientation of living rod-shaped bacteria type *Escherichia coli* by photovoltaic (PV) fields has been recently reported [2].

In this communication, we demonstrate for the first time the versatile capabilities of PVT for massive alignment of anisotropic material on top of PR substrate. To this end, we have chosen zeolite L (ZL) micro-cylinders, a very interesting material with many technological applications [3], some of which require their alignment [4]. We study the role of the crystal configuration and the illumination pattern for obtaining different structures. The theoretical analysis agrees with the experimental results demonstrating that organization of these neutral objects is governed by the dielectrophoretic (DEP) potential whereas ZLs align parallel the PV electric fields.

2. Experimental procedure

ZL Linde Type cylinders of 4 μm length and 1.5 μm diameter have been used due to their high marked anisotropy. In order to fabricate ZL pattern on top of the PR substrate surface, the crystal is illuminated with an appropriate light pattern (at λ = 532 nm, with intensities in the range 1-100 mW/cm^2 and irradiation times around few minutes). After the photo-generation of PR fields, ZLs are deposited on the substrate by immersing the crystal in a suspension of ZLs in hexane [1]. The two different crystal configurations of $LiNbO_3$:Fe used are: *x*-cut (or *y*-cut) that contains the polar axis (*c*-axis) on the surface, and *z*-cut, with the *c*-axis perpendicular to the surface [5].

3. Results and discussion

The *x*-cut substrate has been illuminated with a fringe light pattern (periodicity Λ=18 μm) generated by the interference of two laser beams. Figure 1a displays the obtained particle pattern, showing that ZLs are trapped by PVT following the light periodicity. Inside of each fringe, one can also appreciate that ZLs are aligned horizontally, parallel to the *c*-axis. Simulations of the evanescent PR fields and DEP potential for this configuration have been carried out using a previous reported model [6]. They reveal the existence of a dominant electric field component along the *c*-axis and DEP potential minima with same periodicity of the light, consistent with the ZL alignment and spatial distribution, respectively.

According to simulations [7], *z*-cut experiments should allow vertical alignment of ZLs. Figure 1b shows an illustrative example of a *z*-cut sample that was illuminated using a triangle image (800 µm side) generated using a spatial light modulator. As expected, a high percentage of ZLs is placed vertically in the central area of the triangle (see inset in the figure). However, ZLs trapped in the boundaries of the triangle remain parallel to the surface and radially aligned with regard to the center of the triangle. The corresponding *z*-cut simulation is shown in Figure 1c. It explains satisfactorily the experimental results since the electric field is essentially vertical in almost the whole illuminated area, except at the triangle boundaries where it becomes parallel to the surface.

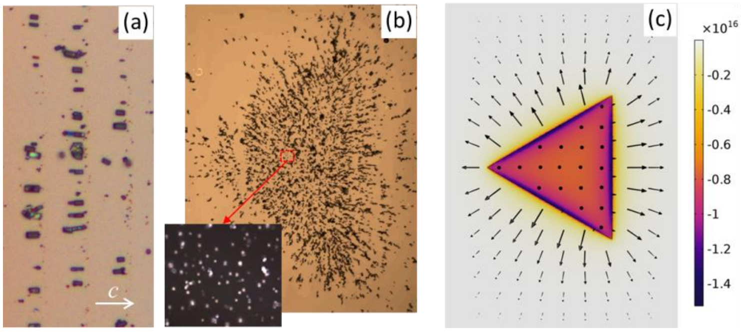

Figure 1: (a) ZL fringe pattern obtained by illuminating a *x*–cut sample with a sinusoidal pattern with Λ=18 µm periodicity, (b) ZL triangle pattern obtained in a *z*-cut sample illuminating with a triangle light image (800 µm side). (c) Simulation of the evanescent PV field (arrows) and DEP potential (colour degrade) for the experiment of the triangle. In both cases, ZLs are aligned along the evanescent electric field lines.

4. Summary and Outlook

The most relevant results of this novel application of PVT are the high flexibility to create different structures of aligned ZLs and the good agreement between theory and experiments. Massive trapping and alignment of ZLs have been reached with low light intensity and in a few minutes. These aligned structures should be very appropriate for further applications such as enhancement of non-linear properties or energy transfer processes, to name just a few.

Acknowledgment

This work was supported by MINECO, project number MAT2014-57704-C3. We would like to thank Tim Buscher and Prof. Armido Studer (University of Münster, Germany) for kindly providing the zeolite L crystals.

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