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1D and 2D neutral particle patterning by dielectrophoretic forces on z-cut Fe:$LiNbO_3$ crystals

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Summary

1D and 2D patterning of neutral micro- and nanoparticles via dielectrophoretic forces on z-cut Fe:$LiNbO_3$ have been investigated for the first time. The results show the capability of this technique for high quality 2D patterning, and its universality, in the sense that/since can be used with any kind of charged or neutral particles.

Introduction

Trapping and manipulation of micro- and nano-objects is a fundamental issue for many applications in nano- and bio-technology. One method, recently proposed, manipulates particles via dielectrophoretic (DEP) and/or electrophoretic (EP) forces associated to the evanescent electric fields generated by the photovoltaic (PV) effect on the surface of certain ferroelectrics [1-3]. These fields can reach values as high as 10^4-10^5 V/cm for Fe doped $LiNbO_3$ [4] and depend on the doping level and light exposure. The method, that may be considered as a type of photoelectric tweezers, often called photovoltaic tweezers [4], presents a great potential that is now under investigation [5,6].

However, PV tweezers have shown so far a limited capability for 2D patterning. This is due to the directional character of the PV effect along the polar direction (c-axis) of the crystal that in previous experiments is parallel to the crystal face. Only, very recently Esseling et al [7] have used z-cut (polar axis perpendicular to the surface) $LiNbO_3$:Fe (LNFe) obtaining high fidelity 2D-patterning. However, they could only organize charged particles using electrophoretic forces. In this contribution we extend the results demonstrating 1D and 2D patterning of neutral particles trough PV DEP forces. The technique has been successfully applied with dielectric $CaCO_3$ microparticles and Al metal nano-particles. To evaluate the advantages of the new configuration particle patterns obtained with the same light distribution in x- and z-cut substrates are compared.

Results and discussion

The experiments have been carried out in 1mm thick *z*-cut congruent $LiNbO_3$ crystals highly doped with iron (0.1% wt) in order to have a strong photovoltaic effect. A x-cut crystal with the same properties is also used for comparison. Dielectric $CaCO_3$ microparticles (diameter d ~ 1-3 μm) and metallic Al nanoparticles (d~70 nm) have been used. After substrate illumination (λ=532 nm) with 1D sinusoidal or 2D patterns, the neutral particles were deposited from a non polar hexane suspension in which the substrate is immersed. The particle distribution was visualized by micro-photographs.
To check the suitability of z-cut crystals to trap neutral particles via DEP forces we have first addressed 1D patterning under sinusoidal illumination. In fig.1 we show the results with $CaCO_3$ (1a) and Al (1b) particles. The spatial light period Λ is 50 and 30

μm for (1a) and (1b), respectively. It can be emphasized that good quality periodic patterns with the same periodicity of light have been obtained in both cases, showing the viability of the z-cut configuration.

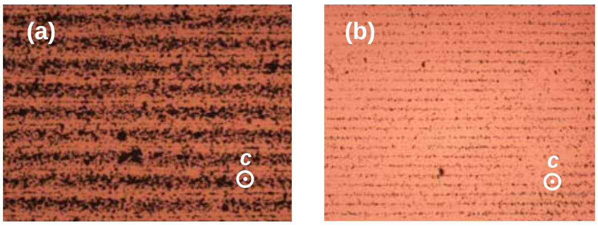

Fig.1 Micro-photograph showing 1D periodic structuring in z-cut LNFe of $CaCO_3$ (a) and Al (b) particles. The particle periods are 50 (a) and 30 (b) microns.

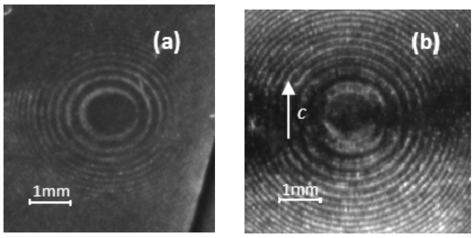

Fig. 2. $CaCO_3$ particle patterns obtained from a Fresnel lens type light pattern using (a) z-cut and (b) x-cut substrates.

In order to demonstrate successful 2D patterning using z-cut substrates a Fresnel lens type light distribution obtained from a spatial light modulator has been projected onto the sample. The obtained pattern is shown in fig.2a together with the corresponding pattern generated in a x-cut substrate (fig.2b) for comparison. The z-cut pattern exhibits a really good fidelity for any direction whereas the x-cut pattern is well defined for fringes perpendicular to the z-axis but disappears in the regions with fringes parallel to it (central horizontal region in fig.2b). Then, z- samples result to be much better templates for PV 2D neutral particle patterning. Finally, to further investigate the 2D patterning capabilities of PV tweezers in z-cut we have carried out several experiments with the smaller neutral metallic particles of Al. Two illustrative results are shown in fig.3. It can be observed the good quality of the patterns that are an accurate replica of light patterns with even better definition than the one obtained with $CaCO_3$ (see fig.2a) probably due to the smaller diameter of the particles.

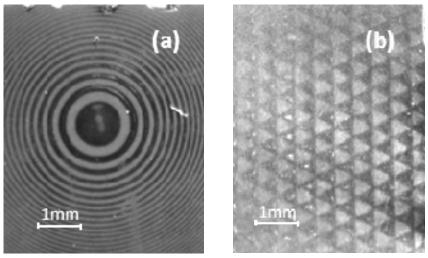

Fig.3. Al patterns on z-cut substrates obtained using two different 2D light patterns.

In summary, z-cut Fe:$LiNbO_3$ substrates have demonstrated to develop space charge fields that are a replica of the light pattern distribution and that are able to trap and organize by DEP forces neutral micro- and nano-particles in 1D and particularly in 2D structures. These results are an additional confirmation of the interest of this methodology for manipulation and patterning of micro and nanoparticles.

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