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Particle Patterning on Lithium Niobate waveguides via photovoltaic tweezers

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Abstract: Successful micro and nano-particle patterning on iron doped lithium niobate waveguides using photovoltaic fields is reported. This technique previously used in bulk crystals is here applied to waveguide configuration. Well defined particle patterns are obtained using two types of planar waveguides (by proton exchanged and swift heavy ion irradiation) and metallic and dielectric neutral particles. The use of waveguide configuration has allowed a reduction of the light exposure time until 3 s, two orders of magnitude smaller than typical values used in bulk.

Dielectrophoretic (DEP) trapping and patterning of micro/nanoparticle using the electric fields generated by the bulk photovoltaic (PV) or more generally by the photorefractive (PR) effect in PR materials is an emergent field (see [1] and references therein) very promising for applications in nanophotonics and nanotechnology. Using this methodology (often called photovoltaic tweezers) remarkable patterning of dielectric dielectric and metallic particles has been achieved [1-4]. As an illustration an Al (d~70 nm) nano-particle pattern on Fe:$LiNbO_3$ is shown in fig 1.

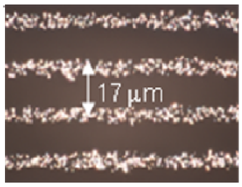

Fig1. Al nano-particle periodic pattern

In order to extend the applicability of PV tweezers in combination with integrated and/or opto-fluidic devices we have attempted particle trapping on PV photovoltaic waveguides. In this communication we present successful results for two types of Fe-doped $LiNbO_3$ waveguides obtained by soft proton exchanged (SPE) [5] and swift heavy ion irradiation (SHI) [6].

The PV fields are induced by the interference of two beams propagating through the waveguide. Then, two deposition methods have been tested: A) to blow out the particles on the sample in air or B) to immerse it in a non polar suspension of the particles. In fig. 2 we present representative results obtained with $CaCO_3$ (d~1-3 mm) in air (method A), and Al (d~70 nm) in hexane suspension (method B), for SHI waveguides. Particle patterns have been also obtained on SPE waveguides but the fringes have a lower quality and contrast.

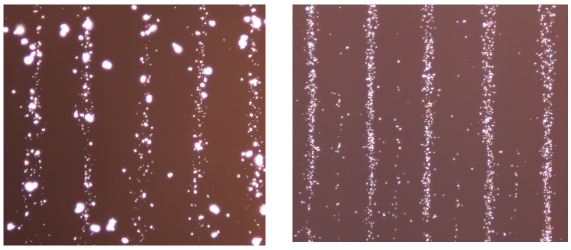

Fig 2. Microphotographs of the particle patterns deposited after sinusoidal light illumination (Λ=55 µm) during 10 min with $CaCO_3$ (left) and Al (right) particles and using method A and B respectively.

One of the potential advantages of using a waveguide configuration is the high light intensities reached in the waveguide and so, the faster recording of PV fields with regard to bulk crystals. To check the possibility of working with shorter time responses we have performed a set of experiments with decreasing times from 10 min (typical value for bulk experiments) to 3 s with $CaCO_3$ microparticles. Particle patterns have been obtained for all the time periods tested. In fig. 3 we can see the corresponding particle pattern for the shortest time of 3 s. It can be seen that a well defined and clean pattern is obtained showing the possibility of reducing two orders of magnitude the time exposure.

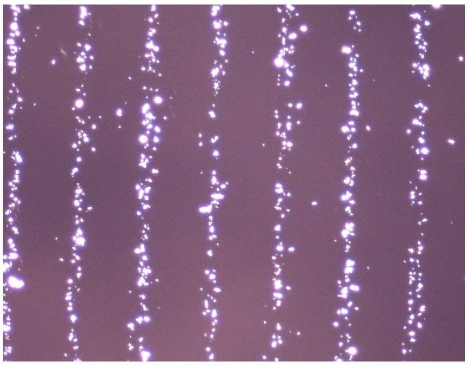

Fig 3. Microphotograph of a particle pattern deposited after sinusoidal light illumination (Λ=65 µm) during 3 s with $CaCO_3$ using method B

In summary, the use of PV tweezers in waveguide configuration allows to obtain well resolved particle patterns. It can be potentially applied to any kind of particles and enables the reduction of the PV time response. The results indicate the flexibility of this emergent methodology showing its suitability for application in integrated optical configurations.

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