Applications of photovoltaic fields of iron doped $LiNbO_3$ in nanotechnology

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As it is well known, the bulk photovoltaic effect (PVE) [1] appears in certain crystalline materials (usually ferroelectrics), that show an asymmetric crystal cell unit arrangement. It produces a directional electronic drift when electrons are excited to the conduction band through visible light illumination. The drift induces a charge separation and generates an electric field between the illuminated edges of crystal. Reported measurements of this electric field reach values as high as 10^5 V/cm in the material employed in our experiments, i.e. iron doped $LiNbO_3$ [2].

In this communication we will summarize our results in two applications of the PV fields in nanotechnology i) micro/nanoparticle trapping and structuring on the surface of $LiNbO_3$ crystals, and ii) Effects of PV fields of $LiNbO_3$ micro- and nano-particles in tumour cells.

As photovoltaic material we have used congruent $LiNbO_3$ with a 0.1% wt Fe doping ([Fe]=4.25×10^{19} cm^3). In these crystals, photovoltaic fields in the range 50-70 kV/cm have been measured using optical techniques.

Particle trapping and structuring

Recently, a method based on the evanescent fields generated by the bulk photovoltaic effect in iron doped $LiNbO_3$ has been proposed and first experiments reported [3-5]. The main advantage of this procedure for particle trapping is that the involved electrophoretic and/or dielectrophoretic forces do not require any electrodes and massive manipulation of nanoparticles can be achieved using the patterning capabilities of light. Then, we have developed a set of experiments with different kind of particles, either dielectric (CO_3Ca, polystyrene) or conducting (graphite, aluminium and silver). Holographic patterns as well as single beam illumination have been used. The data are analyzed within a theoretical scheme we have recently proposed [6]. The results allow for a more meaningful assessment of the possible applications of the PV effect for trapping and patterning of nanoparticles. As an illustration, Fig. 1 shows the particle arrangements obtained using dielectric (CO_3Ca, diameter ~ 1 μm) particles (a), and metallic (silver, diameter ~ 100 nm) particles, (b), under periodic light pattern with spatial periodicity Λ = 20 and 10 μm respectively. In all cases the periodicity of the obtained pattern was the same to that of the exciting light.

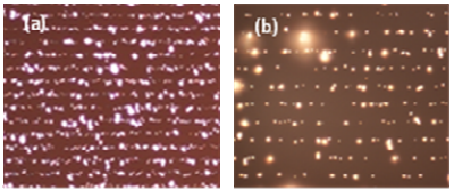

Figure 1 Particle pattern obtained on the surface of $LiNbO_3$ plates after sinusoidal illumination with period Λ : (a) $CaCO_3$ particles (Λ=20 μm) (b) silver particles (Λ=10 μm)

Biomedical applications

We have recently demonstrated the effect of PV fields on biological media by culturing tumour cells on Fe:$LiNbO_3$ plates. A massive necrotic cell death was induced in human tumour cell cultures after irradiation with low intensity visible light [7]. In order to explore the potential of PVE for future biomedical applications we are now investigating the effect of $LiNbO_3$:Fe micro-nanoparticles on tumour (HeLa) cell cultures. In a first experiment cells were incubated with microparticles (1-3 µm diameter). Cells did not show any morphology change in dark whereas after 60 min irradiation (546 nm, 133.2 J/cm^2 light dose), about half of the cells had a round and refringent aspect, i.e. they show a certain damage. Two hours after ending illumination most cells were necrotic as represented in Figure 2. Control cultures (without microparticles) exposed to 546 nm light for 60 min showed no damage.

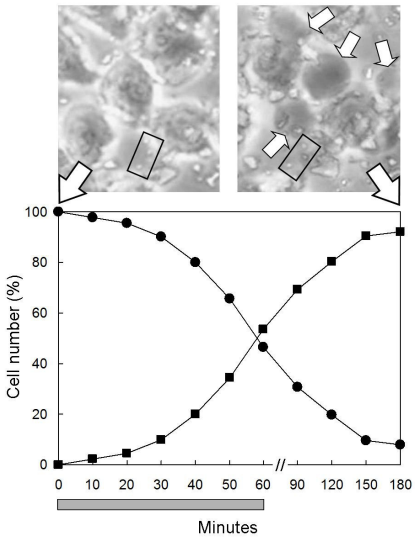

Figure 2. Time evolution of the number of viable (circles) and necrotic (squares) cells evaluated through morphological criteria for HeLa cell cultures with LNB micro-particles. Representative viable and necrotic cells are shown in the microphotographs at the top of both figures. The gray bars indicate the period of green light exposure.

The next step is to reduce particle size to a diameter in the range 10-100 nm to induce their incorporation by cells. Experiments to evaluate the effect of nanoparticles in cells for different light doses are now in progress.

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