Phototoxicity induced by Iron-doped $LiNbO_3$ nanoparticles in human tumor cells

A. Blázquez-Castro[1], J. Espada[3], J.C. Stockert[4], F. Agulló-López[2], A. García-Cabañes[1], and M. Carrascosa[1]

1. Department of Physics of Materials, Autonomous University of Madrid, 28049, Madrid, Spain

2. Center for Microanalysis of Materials (CMAM), Autonomous University of Madrid, 28049, Madrid, Spain

3. Institute for Biomedical Research "Alberto Sols", High Council for Scientific Research (CSIC)-Autonomous University of Madrid, 28029, Madrid, Spain

4. Department of Biology, Autonomous University of Madrid, 28049, Madrid, Spain

alfonso.blazquez@uam.es

Abstract

As it is well known that the Bulk Photovoltaic Effect (BPE) appears in certain crystalline materials (usually ferroelectrics) that show an asymmetric cell unit arrangement [1]. This spatial pattern produces a directional electronic drift when electrons are excited to the conduction band as a result of visible light absorption by the material. This drift induces a charge carrier separation and generates an electric field between the illuminated edges of the crystal. Reported measurements of this electric field show values as high as 10^5 V/cm in iron-doped $LiNbO_3$, the material employed in our experiments [2].

In this communication, preliminary results regarding the use of photovoltaic fields generated in Fe:$LiNbO_3$ nanoparticles for damaging human tumor cells in culture will be presented. These results are an extension of those we have previously obtained after exposing eukaryotic cell cultures to both macroscopic and microscopic crystals of iron-doped $LiNbO_3$ in the presence of visible light [3]. Also, they are in line with recently published results of pyroelectric damage to prokaryotic cells that showed a reduced viability when incubated with $LiNbO_3$ nanoparticles and then exposed to temperature cycles [4].

Iron-doped $LiNbO_3$ nanoparticles were obtained by grounding a crystalline sample in an agate mortar until a very fine powder was produced. This powder was suspended in a phosphate buffered solution (PBS) for 24 h to separate the submicrometric fraction present in the original sample. This submicrometric fraction remained in suspension in the liquid, while the coarser particles precipitated. An example of the obtained particles is shown in Figure 1.

Human tumor cells (HeLa cell line) were cultured and grown on Petri dishes. After reaching a certain degree of confluence, the cell cultures were exposed to the iron-doped $LiNbO_3$ nanoparticles. Immediately some cell cultures were also exposed to visible light provided by the water-filtered output of a halogen lamp, while others were kept in the dark. Cell morphology was evaluated 24 h after treatment as a measure of cell damage. Controls showed a normal morphology, with the typical spread polygonal shape of HeLa cells (Figure 2A). Cells exposed to iron-doped nanoparticles and visible light showed, in general, a certain degree of retraction, as can be seen in Figure 2B, which is an early sign of cell damage. Also, there are some cells that display the typical late apoptotic cell death morphology. These cells show a collapsed and smaller cell body, with increased surface roughness. Some examples of apoptotic cells are indicated by arrows in Figure 2B.

These results are the first obtained in regard to the phototoxic activity of iron-doped $LiNbO_3$ nanoparticles. Further research is underway to expand the results in this new area of the BPE applied to the life sciences.

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References

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Figures

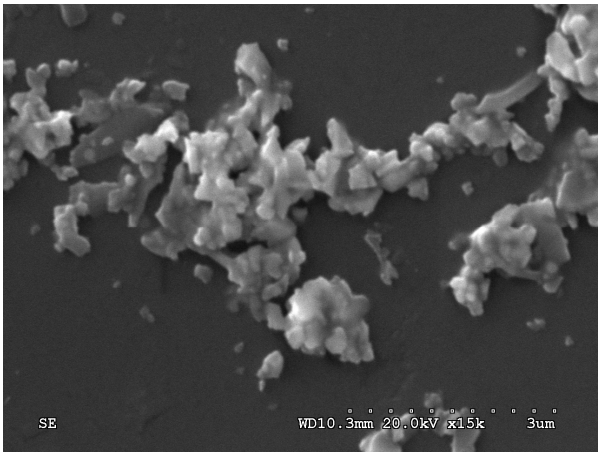

Figure 1. Scanning electron microscopy (SEM) image showing the size and shape of the iron-doped $LiNbO_3$ particles employed in the biological experiments.

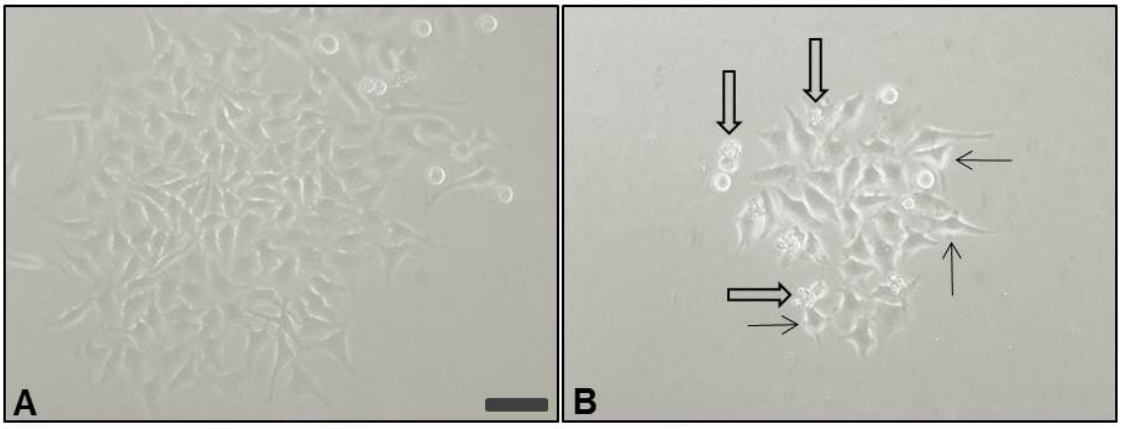

Figure 2. Cell damage and death induced after exposure of cell cultures to iron-doped $LiNbO_3$ nanoparticles followed by illumination with visible light. Control cell cultures are shown on the left (Fig.2A). These cells appear with a normal morphology. On the right an image of cells exposed to iron-doped $LiNbO_3$ nanoparticles and visible light (light irradiance 267 mW/cm^2) for 60 min. Many cells show a certain degree of body retraction (arrowheads), which denotes some amount of cell damage. Also, there are some dead apoptotic cells (arrows). The combined treatment of nanoparticles and light results in tumor cell death. Scale bar: 100 µm.