Light and thermally-induced charge transfer phenomena at ferroelectric crystal surfaces

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Lately, evanescent electric fields generated by the bulk photovoltaic (PV) effect and the pyroelectric (PY) effect have attracted significant interest for multiple applications (particle/droplet manipulation and trapping [1-4], droplet dispensing [5-6], electro-wetting [3], orientation of liquid crystals [7], etc). In this context, the ferroelectric surface plays a key role, and we have discovered a new interaction mechanism when ferroelectrics come into contact with other objects, exploiting the PV and PY effects. On one hand, in this work we present experimental evidence of charge transfer between ferroelectric crystals and micro/nanoparticles in contact with their surface, driven by optical or thermal stimuli [2, 8]. On the other hand, we have taken this new mechanism one step further and demonstrated the feasibility of transferring PV/PY-induced surface charge patterns to passive dielectric substrates.

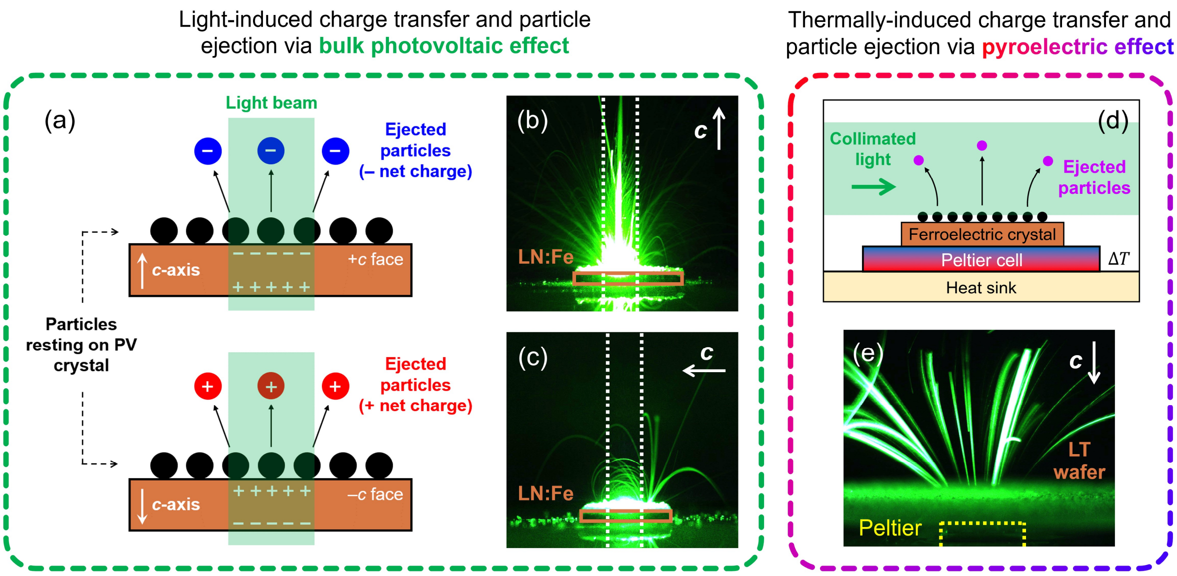

Figure 1: a) Illustration of the charge transfer and ejection of particles from *z*-cut ferroelectric PV crystals triggered by light excitation. Images b) and c) show the ejection of Al_2O_3/ $CaCO_3$ microparticles from *z*-cut/ *x*-cut $LiNbO_3$:Fe, respectively. The white dotted lines indicate the position and diameter (3 mm) of the light beam ($\lambda = 532$ nm, $I = 86$ mW/cm^2). d) Experimental configuration for observing thermally-driven ejection of particles from ferroelectric surfaces. e) Ejection of $CaCO_3$ microparticles from *z*-cut $LiTaO_3$ upon local cooling ($\Delta T \approx -16$ °C, Peltier area: 9×9 mm^2).

Regarding the first aspect, i.e. charge transfer to micro/nanoparticles, we have thoroughly studied the influence of the type of particle (metallic or dielectric), crystal orientation, light intensity, wavelength and surrounding medium. Furthermore, although most experiments have been conducted with $LiNbO_3$:Fe (LN:Fe) crystals, we have also tested the effect in other ferroelectrics (such as $LiTaO_3$), thanks to the generality of the PY effect. In Figure 1 we summarize our results.

More recently, we have also investigated the feasibility of another kind of charge transfer, from the ferroelectric surface to a passive dielectric substrate, and even the possibility of transferring micrometric charge patterns. The proposed procedure is simple and resembles the operation of a stamp: upon contact, part of the PV/PY charge generated in the ferroelectric is transferred and stored at the surface of the dielectric substrate. The method has been successfully applied with glass, quartz and PMMA passive substrates, and the transferred charge patterns have been exploited to massively trap and pattern nanoparticles. A representative result is shown in Figure 2. A very similar particle distribution can be observed on the active ferroelectric crystal and the passive dielectric substrate, indicating a successful charge transfer that keeps the original pattern generated at the ferroelectric surface. Moreover, from a practical point of view, the results show the possibility for nanoparticle trapping and patterning in common passive substrates instead of LN:Fe.

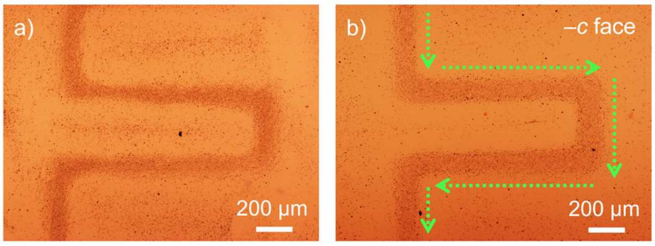

Figure 2: a) Pattern of Ag nanoparticles on a quartz substrate after contacting a *z*-cut LN:Fe crystal illuminated with a scanning Gaussian beam ($\lambda = 532$ nm, $1/e^2$ diameter of 150 µm, , intensity $I =$ 29 W/cm^2, average speed of around 50 µm/s). b) Counterpart directly on the *z*-cut LN:Fe substrate illuminated with the same light pattern. The trajectory of the laser beam is indicated by green dotted arrows.

Overall, different charge transfer phenomena from the ferroelectric surface are reported here, which open the way towards novel functionalities and applications of ferroelectric platforms.

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