Electrophoretic vs. dielectrophoretic forces in 2D optoeletric nanoparticle patterning

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Photovoltaic tweezers (PVT) are a recently developed optoelectric technique for flexible particle trapping and patterning on the surface of certain ferroelectrics [1]. It is based on the light induced electric fields generated in those materials via the bulk photovoltaic effect. It has been already applied with both inorganic and biological objects and it is becoming a very competitive and flexible tool for particle manipulation and patterning (see [1] and references therein).

This technique has been mostly used with neutral micro and nanoparticles (NP), manipulated through dielectrophoretic (DEP) forces, although a few cases of electrophoresis (EP) of charged particles have been also reported [2,3]. Moreover, very few data on the comparison between EP and DEP particle patterning and on the different features of the obtained structures are available. In this work we have investigated this issue by theory and experiments to clarify the advantages of each regime.

Theoretical predictions are based on a previously developed theoretical model [4] for DEP forces that is here applied to calculate the EP and DEP potentials for arbitrary 1D and 2D light distributions. Simulations show different EP and DEP potentials for a given light distribution, so dissimilar features are expected also for the corresponding particle patterns. Specifically, DEP potential profiles seem to better reproduce the light pattern although they present an edge enhancement effect. To confirm these predictions we have addressed a number of experimental tests.

In the patterning experiments z-cut $LiNbO_3$:Fe crystals are used to generate the photovoltaic electric fields by illumination and to trap aluminium NP (∅=70nm) on their surface. The light intensity distribution used is identical to that of the simulations. Afterwards, the crystal is immersed in a hexane suspension of the NP and the pattern is generated on its surface.

The experimental results on NP patterning basically agree with the theoretical predictions and confirm the differences between EP and DEP deposition and the better fidelity to the light pattern exhibited by DEP-deposited nanostructures. An example is presented in Figure 1 where the microscope images of the particle patterns obtained by illumination with a chequered light pattern are shown for charged (a) and neutral (b) aluminium NP. In the central column (c),(d), the corresponding averaged particle concentration profiles along the horizontal direction are plotted. Finally, on the right (e), (f), numerical simulations for the EP and DEP potentials generated by a single square are shown to compare with experiments. In both microscope images the periodic pattern can be clearly seen although the definition of the squares is much better for DEP deposition (b),(d) whereas the boundaries are blurred in the EP case (a),(c). These features are in a good accordance with the simulated DEP and EP potentials. Therefore, the obtained results confirm the ability of PVT to pattern neutral and charged NP, but showing differential features between the two cases. Moreover, the theoretical model successfully describes the experiments and should allow a further optimization of the obtained NP structures in both EP and DEP regimes, increasing their potential for applications in fields such as MEMS or plasmonics.

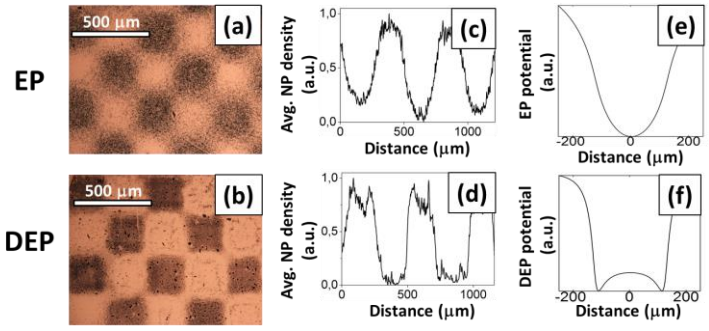

Figure 1 (a, b) Chequered pattern (square side 250 μm) of charged (a) and neutral (b) aluminium NP; **(c, d)** Particle density profile along a row of the patterns showed in (a) and (b) respectively; **(e, f)** Simulation of the EP (e) and DEP (f) potential generated by a single square illumination.

References

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