RAPID ELECTROKINETIC PATTERNING
OF COLLOIDAL PARTICLES
WITH OPTICAL LANDSCAPES
Aloke Kumar, Stuart J. Williams, Steven T. Wereley
Birck Nanotechnology Center and School of Mechanical Engineering,
Purdue University, West Lafayette, Indiana, USA

ABSTRACT
Manipulating and assembling micro- and nanoparticles is important for a variety of micro-engineering applications including developing lab-on-a-chip technologies and creating crystalline particle architectures. We demonstrate an opto-electrokinetic technique for non-invasive particle manipulation on the surface of a parallel-plate indium tin oxide (ITO) electrode that is biased with an alternating current (AC) signal and illuminated with near-infrared (1064nm) optical landscapes. Particle groups are dynamically and rapidly assembled at low frequencies (<100kHz).

KEYWORDS: Nano-assembly, micromanipulation, opto-electronic platform

INTRODUCTION
The ability to control the arrangement of particle groups is important for the development of artificial architectures. Planar assembly of colloidal particles has been earlier realized with an applied low-frequency AC signal [1,2] which has been modulated with illumination geometries onto a photosensitive platform [3]. Here, we introduce a new opto-electronic mode of dynamic patterning of particles with low AC frequencies (<100 kHz). By using holograms created by high power lasers we have substantially decreased the time required for such patterning thus leading to a rapid electrokinetic patterning (REP) of micro- and nanoparticles. Computer generated holograms enable a dynamic control of these illuminated patterns, which enables REP to be utilized for manipulating colloidal particles.

EXPERIMENTAL & THEORY
Figure 1 illustrates the REP process. A liquid sample laden with particles is introduced between two unpatterned indium tin oxide (ITO) coated glass substrates. The ITO electrodes are separated by a 50 µm spacer. An AC signal with a maximum bias of 20 volts peak-to-peak ($V_{pp}$) is applied between the parallel electrodes. Near-infrared (1064 nm) light patterns are generated from a laser-based holographic system (Bioryx® 200 from Arryx Inc., Chicago, USA), with a maximum applied power of 40mW. Various particles (polystyrene, latex, and silica) ranging in size from 300nm to 3µm are suspended in low conductivity water (~20 mM KCl) and used to demonstrate particle patterning abilities of the platform. A Nikon 60X water-immersion objective lens (1.3 NA & 0.27 mm working distance) was used for the illumination patterns and observation. To accommodate this short working distance
an ITO-coated glass cover slip (~170 μm thick) was used for the bottom electrode substrate.

Figure 1. The highly-focused illumination generates electrohydrodynamic vortices that carry particles towards the surface of one ITO electrode. Optically-induced electrokinetic effects capture groups of particles near this surface.

There are several electrokinetic phenomena that were observed during REP. First, localized fluid heating generates gradients in electrical permittivity and conductivity which, in the presence of an electric field, induces a body force on the fluid [4]. For these experiments the highly-focused optical illumination is the dominant source of non-uniform heat. The resulting fluid flow profile is toroidal, with its center located at the laser focal point (Figure 1). The velocity of the microvortex depends on the illumination intensity, the dielectric properties of the fluid, and the voltage and frequency of the applied AC signal [5]. This vortex carries suspended particles towards its center where they aggregate with applied AC frequencies less than 100 kHz. Low-frequency planar colloidal aggregation has been investigated previously [1-3] and their formation was attributed to induced electrohydrodynamic flows near electrodes that carry particles towards each other and into densely packed assemblies. These particle assemblies are patterned in and around the illuminated regions of the ITO, as this material is photosensitive in the infrared [6]. In addition, the electrohydrodynamic vortices accelerate this electrokinetic particle patterning.

RESULTS AND DISCUSSION

Results presented here use fluorescent 690 nm polystyrene beads (Duke Scientific, CA, USA) although similar results have been achieved with polystyrene, latex, and glass beads with diameters ranging from 300 nm to 3 μm. Figure 2 exhibits the accumulation of over one-hundred particles within ten seconds. Figure 3 illustrates an ‘L’ shaped particle aggregation containing hundreds of particles created by shining a similar-shaped light pattern onto the ITO electrode. These holograms can be altered in real-time, hence all of these patterns can be dynamically configured.
CONCLUSIONS
Dynamic particle patterning using optical landscapes operating at 1064 nm coupled with an ITO platform is demonstrated. This platform can generate microfluidic vortices, enhancing electrokinetic aggregation. REP can be used as a non-invasive micro-manipulation tool and shows promise as an alternative to other methods including optical tweezers and dielectrophoresis.

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