Patterning of Nanoparticles Using Electric Field Assisted Coffee Ring Effect

Jinhua Mu[1] and Qiangfei Xia[2]*

[1]*Department of Physics*, [2]*Department of Electrical and Computer Engineering, University of Massachusetts, Amherst, MA 01003*

Coffee ring effect is a phenomenon of ring-like pattern left by solutions of particles after it evaporates out on the surface. Edge-ward capillary flow caused by differential evaporation rate carries almost all of particles to the edge of the drop [1]. Previously, a restricted geometry such as a sphere on Si substrate was used to guide the formation of gradient concentric ring patterns for polymer particles [2]. Here we report the patterning of concentric rings of metal, dielectric, and polymer nanoparticles using electric field modulated coffee ring effect.

To apply the electric field, we fabricated arrays of Au electrode on a Si wafer with 100 nm thick thermally grown SiO_2. Each set of electrode contains one 3.6 mm-diameter ring (width 60 μm) with a 100 μm-diameter dot in the center (Fig. 1). The center dot was connected to a wavefunction generator that provided alternative current (AC) signal, and the outer ring was electrically grounded. A droplet (~1 μL) of nanoparticle solution was applied to cover the electrode pair. The particles used in this study included 100 nm titanium oxide, 10 nm and 100 nm gold, as well as 350 nm polystyrene (PS).

Without applying the AC signal, regular coffee ring effect was observed (Fig. 2). However, under the electric field, the patterns were much different. Fig. 3 shows patterns of TiO_2 nanoparticles under 5V AC signal with frequencies ranging from 0.1 Hz to 1000 Hz. First, instead of aggregating along the edge, the nanoparticles assembled themselves into concentric rings over the whole area after the droplet dried. Second, the number of rings decreased with the increase of frequency, while the inter-ring spacing increased with higher frequency. Third, at a particular frequency, the inter-ring spacing gradually decreased towards the center. All three trends were also observed for gold and PS nanoparticles.

We believe our findings will open opportunities in many applications such as plasmonics, bio-technologies and modern printing technologies.

[1]. Deegan, R. D. et al *Nature* **389,** 827-829 (1997).

[2]. Hong, S. W.; Xia, J.; Lin, Z. *Adv. Mater.* **19**, 1413-1417 (2007).

* Email: qxia@ecs.umass.edu

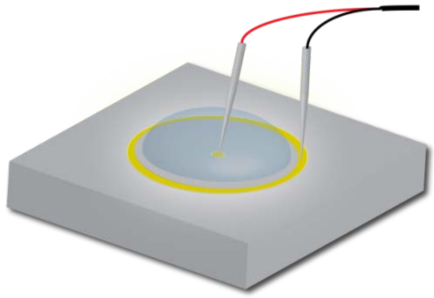

Fig. 1. Schematic of our experiment setup. Red and black lines indicate signal output and grounded probe respectively. Yellow ring and dot inside show the electrode fabricated by EBL and gold evaporation.

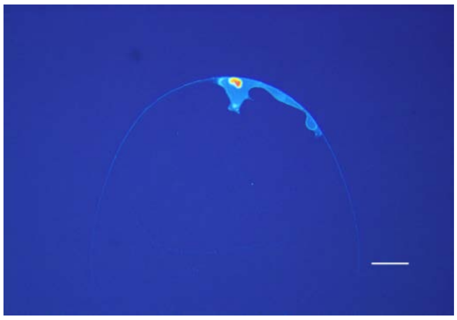

Fig. 2. Regular coffee ring pattern left by TiO_2 nanoparticles. Scale bar is 0.1 mm. Sessile droplet often moves on substrate, thus leaves an incomplete ring pattern.

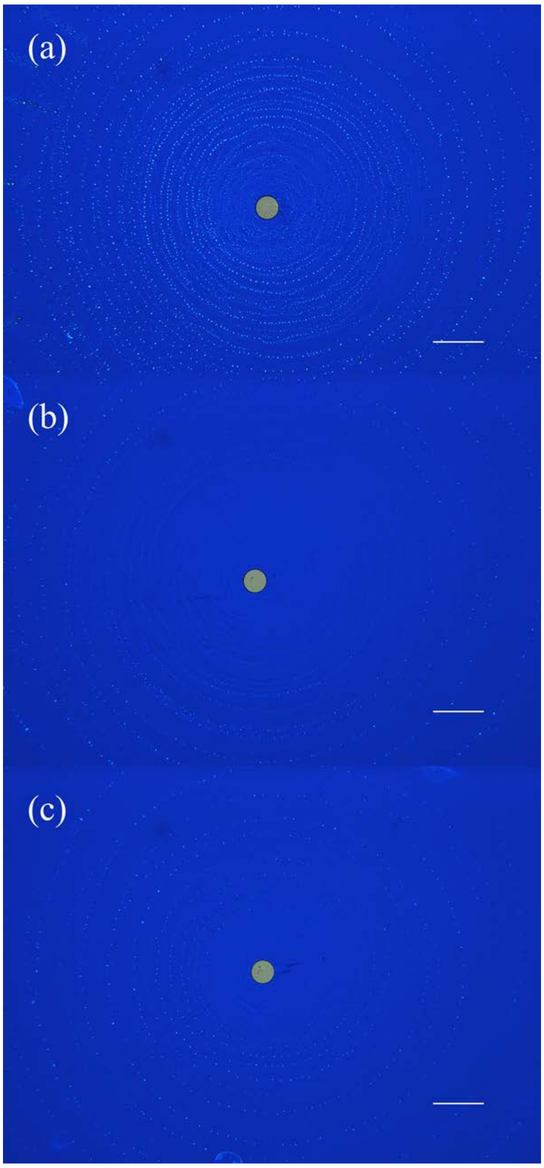

Fig. 3. Optical images of inner concentric coffee rings formed by TiO_2 nanoparticles under increasing frequencies. (a) 0.1 Hz; (b) 10 Hz; (c) 1000 Hz. The yellow dot in the center is part of electrode contacted with signal probe. All of the scale bars in the graph are 200 μm.