Nano Stamp: single molecular stamping of sub-10nm colloidal quantum dot array

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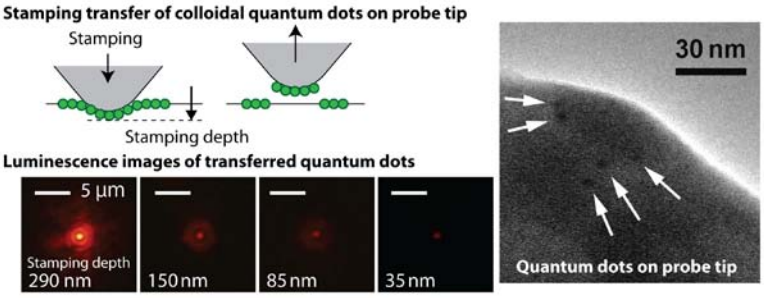
We introduce a nano-scale stamping technique of sub-10nm colloidal quantum dot (QD) arrays to highly localized areas of three dimensional nanostructures, using a quartz tuning fork employed as the stamp pad (the "Nano Stamp"). CdSe/ZnS core-shell nanoparticles with diameters of 9.8 nm were deposited on microfabricated silicon probe tips. The number of transferred QDs, which ranged from several thousands down to single molecular order (less than 10), was precisely controlled by adjusting the stamping depths and angles. The stamping areas were varied from 1.2 µm x 1.2 µm down to 30 nm x 30 nm, respectively. Using the Nano Stamp, QDs can be transferred to varieties of protruding nanostructure. The amount of particles transferred to the tip was assessed by fluorescence intensity measurements, and the number of particles was estimated by direct Transmission Electron Microscope (TEM) observation. Correlation between the fluorescence intensity and the observed stamping depth and the approaching angle of the tip was found, demonstrating the efficacy of our Nano-Stamp technique. Considering the sub-nm control capability of the tuning fork based positioning system, we did not see major technical difficulties which may impede the realization of single molecule deposition at the probe apex in the near future.



Manipulation of colloidal QDs in a very small number is becoming an important issue in fabricating colloidal QD-based devices such as light emitting diodes (LEDs), transistors and bio-chemical sensors. Creation of a nanometer-scale LED at the scanning probe tip is one of our promising applications of Nano Stamp. The Nano Stamp can be further applicable to several kinds of particles and surfaces as have been tested in previous studies of micro contact printing. Our test stamping on the tip of drawn optical fibers, which are commonly used in standard NSOM, showed promising results. A vast variety of particles, including polymer, metal, semiconductor or diamond nanoparticles, can be deposited using the similar procedure. Attachment of fluorescent nanodiamonds at the probe tip is a topic of current interest in magnetometry at the nanoscale. Successful single molecular order transfer of nanoparticles on three dimensional nanostructures leads to creation of future scanning probes, sensors and quantum logic devices.

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