

## INTRODUCTION

Quantum dots (QD), also referred to as nanocrystals, typically measure from 2–8 nm in diameter and possess unique physical properties. On learning a method to effectively manufacture the same in bulk, efforts are on-going to develop an enabling technique to efficiently grow these nanocrystals in a desired manner and location so as to obtain technologically relevant and useful patterns. Thus far, expensive and time consuming techniques such as Molecular Beam Epitaxy (MBE) and electron beam lithography have been widely employed [1]. This application note describes a novel method to directly transfer and pattern QDs with ultramicroscale dimensions.

## DATA SUMMARY

When working with nanoscale objects, one of the more convenient ways to handle their transfer is by altering the working environment to a high boiling point liquid to avoid evaporation. However, this leads to the further challenge of using microfluidics to deliver reproducible volumes of this liquid with high spatial precision. This application note briefly describes how BioForce's nanomaterial printing device, termed the Nano eNabler™ system, can be conveniently used to transfer, array, and even pattern QDs and other nanomaterials on a chemically functionalized silicon surface. The Nano eNabler™ system incorporates a microfluidic MEMS device, termed the SPT™ print cartridge to handle and transfer bio/nano materials [2]. The Nano eNabler™ system is a dedicated biomolecular printing device which does not incorporate any scanning/imaging capabilities and hence should not be mistaken as an atomic force microscope (AFM). The instrument itself features 50 mm of XY travel with 20 nm resolution for high precision patterning over large distances, an integrated optical microscope to observe the process, and an environmental chamber, all of which can be controlled and monitored through a convenient software interface.

QDs were purchased from Quantum Dot Corp. (Hayward, CA). These streptavidin conjugated nanoparticles were mixed 1:1 with BioForce's bio/nano material transfer buffer and loaded into the hydrophilic reservoirs of the SPT. The sample volume loaded was 200 nL, which was sufficient to transfer and continuously pattern lines of well confined QDs.

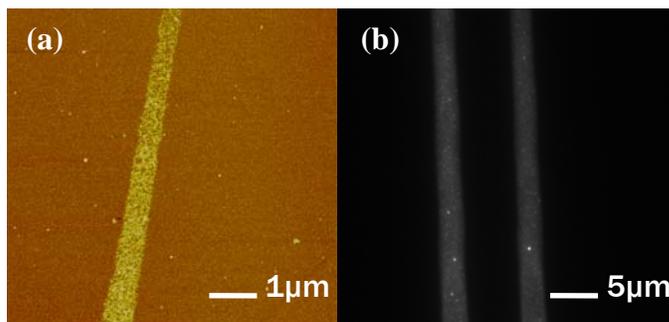


Figure 1. AFM (a) and fluorescence (b) images of QD lines created with the Nano eNabler™ system on a BioForce Sindex chip.

The line in Figure 1a is approximately 500 nm wide and the section shown is only a tiny part of a 3000 μm long line. However, widths ranging from a few hundred nanometers to a few microns can also be easily obtained. More intricate patterns of QDs can also be drawn using the Nano eNabler™ system's lithography software on practically any surface of interest.

## CONCLUSIONS

Selectively growing QDs at precise locations on various semiconductor surfaces can be accomplished, but at a very slow rate and for applications confined to the microelectronic industry. We have demonstrated that continuous, well confined patterns of biologically functionalized QDs can be produced at a well controlled and rapid rate using the Nano eNabler™ system. This technique does not require complex sample preparations or processing. Ultramicro patterns obtained with the Nano eNabler™ system are easy to visualize by atomic force microscopy or fluorescence microscopy. This capability is not only relevant to the microelectronic industry but also to bio/nanotechnology and disease diagnostics.

## REFERENCES

- [1] Bennett, B., Thibado, P., Twigg, M., Glases, E., Magno, R., Shanabrook, B., and L. Whitman. Self assembled InSb and GaSb quantum dots on GaAs. *J. Vac. Sci. Technol. B* **14** (3): 2195-2198, 1996.
- [2] Xu, J., Lynch, M., Huff, J., Mosher, C., Vengasandra, S., Ding, G, and E. Henderson. Microfabricated quill-type surface patterning tools for the creation of biological micro/nano arrays. *Biomedical Microdevices* **6:2**: 117–123, 2004.