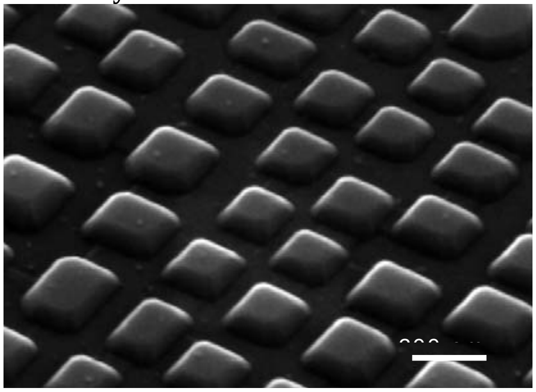
# Micro- and Nanoscale Devices for DNA Dynamics and Separations

## Summary



With researchers finding new and exciting uses for smaller and smaller pieces of DNA, tools are required to examine and separate small fragments of DNA. Micropillar arrays have been used to study large DNA pieces, but smaller pieces require nanoscale architectures. To date, nanofabrication of such structures requires costly equipment, time-consuming cleanroom processes, or exotic materials.

The nanoislands presented here are produced via self-assembly and cost just a few dollars per chip. They can be produced in variable sizes, hundreds at a time, with minimal labor. Future research is focusing on controlling feature size and reproducibility precisely.

Lambda phage DNA is shown elongating in the nanoislands, but theoretically much smaller fragments may be used. Future work will emphasize the separation of smaller fragments of DNA.

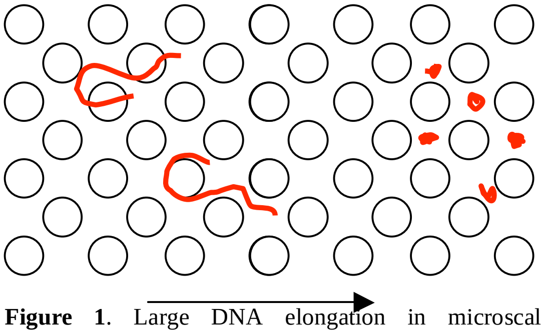


**Figure 1**. Large DNA elongation in microscale architectures; Small DNA do not elongate *Y. C. Chan, et al. J. Micromech. Microeng. 16 (2006) 699*

In order to produce very low cost nanoscale devices, some researchers have turned to self-assembly. To date, self-assembly has been widely employed to create nanoscale layers of materials, but creating two-dimension controlled features has been much more challenging. Biological applications for those features remain rare.

## Nanoisland Fabrication

The nanoislands are created in a two-step process whereby a thin layer of one ceramic is sputtered onto a substrate made of a second ceramic. The two-layer material is then baked for several hours. After heat treatment, the sample emerges with the nanoislands pattern.

**Table 1**. Materials in Nanoislands:

| | |
|---|---|
| GDC | Ce0.89Gd0.11O1.95 (fluorite) |
| YSZ | 9 mol% yttria stabilized ZrO2 (fluorite) |
| Single crystal: (100) orientation | |

The substrate layer is yttria-stabilized zirconia (YSZ). The layer that is sputtered is gadolinia-doped ceria (GDC). Sputtering is achieved with an RF Magnetron sputtering unit.

After sputtering, the work piece is placed in a furnace where the temperature is ramped up to approximately 1100ºC over the course of several hours to days. The ramp rate, residence time, and end temperature all affect the development of the islands. Precise relationships between the variables are still being fully characterized.

If a thick layer is deposited, it will crack and break away, known as "spalling". Beneath the spalled regions will remain highly regular, well-aligned nanoislands. However, spalling does not always occur over the entire work piece. If a thinner layer of GDC is deposited, nanoislands will form, but with less regularity and periodicity. Although they do not have the same degree of morphological similarity, these nanoislands form over the entire surface and do not require spalling.

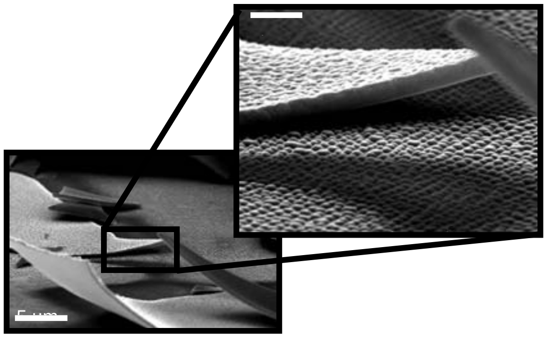


**Figure 2**. Nanoislands form beneath spalled regions

lee.31@osu.edu

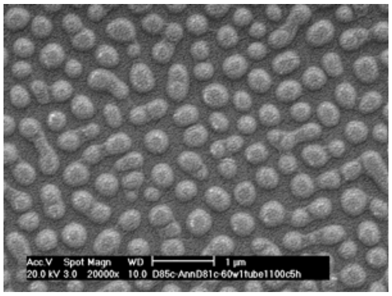


**Figure 3**. Nanoislands formed on unspalled sample

## Microfluidic Device Design

To create a microfluidic device suitable for DNA examination, several design criteria were required. First, the device must permit fluid flow and sufficiently confine flow to the nanoislands. This requires a lid to be bonded to the surface. The lid must also be thin enough to image through it. Because of the small size of DNA, high magnification oil-immersion lenses must be used; these lenses have working distances of 150µm or less, thus requiring a cover slip (or thinner) lid.

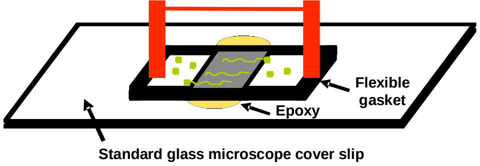


**Figure 4**. Microfluidic Device Design

A very simple design sufficed for initial experiments. The nanoislands chip was bounded using an epoxy adhesive. A flexible gasket was used to encircle the chip to create reservoirs for the DNA solutions. Flow was achieved via two mechanisms: first, pressure-driven flow using capillary action, and second, electrophoretic flow using a DC voltage. DNA is negatively charged, so it will migrate in an electric field.

## DNA Elongation

Lambda DNA was elongated in the device and captured using high-speed video. Images show the DNA snaking around the islands, showing that stretching is due to confinement and is not purely hydrodynamic focusing.

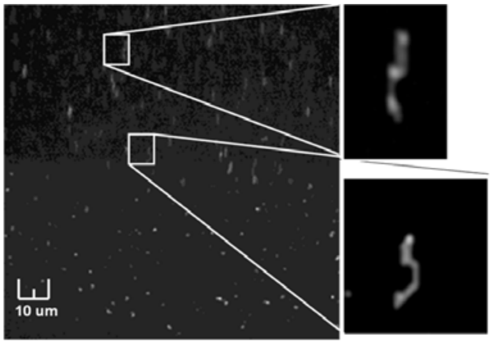
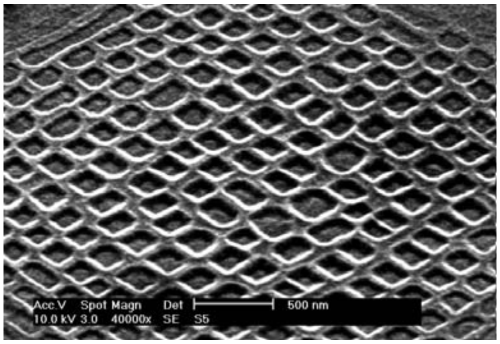


**Figure 5**. DNA Elongation in Nanoislands. Side images show DNA flowing between islands.

## Nanoscale Pattern Transfer

We have also demonstrated the ability to transfer the nanoisland pattern to soft materials. Below, we show a "nanowaffle" in PDMS (Sylgard 184).



We expect to be able to transfer to other soft materials including polymer melts (hot embossing).

## Publications

1. Self-assembly of pseudo-periodic islands on YSZ-(100). M.D. Rauscher, et al. Advanced Materials, Accepted.
2. DNA dynamics and separations using self-assembled ceramic nanoislands. L.B. Zimmerman et al. In preparation.

lee.31@osu.edu