Real time and real space observation of fluids on and in a bionanotube

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While microfluidic devices enjoy widespread popularity, the properties of fluids and flow processes at the nanoscale, especially for fluid confinement below 30 nm, are largely unknown. The main experimental hurdle is the design of channels that are chemically and structurally well defined down to (nearly) atomic dimensions.

Tobacco mosaic virus (TMV) is a tube-shaped nanoobject with 4 nm inner diameter, which is indeed structurally and chemically defined [1]. The diffusion of metal ions into TMV has already been used to construct one-dimensional nanostructures [2]. We integrated single TMVs in micro- and nanofluidic devices, with aid of nanofabrication techniques. E.g., electron beam lithography (eBL) was employed to construct hydrophobic barriers to prevent fluid movement on TMV's outer tube surface (Figure 1). Due to TMV's surprising chemical and thermal stability, it is compatible with positive (PMMA) and negative (mrEBL6000.1) eBL resists, both spin-coated from anisole solution (Figure 2).

We conducted dynamic fluidic experiments by NADIS [3] and ESEM [4]. NAnoDISpensing allows placing sub-microscale droplets of non-evaporating liquids from an AFM cantilever. With this technique we deposited droplets of various sizes at both ends of a single TMV tube, and imaged virus and droplets with AFM. The flow speed through the virus was much smaller than expected from related micro- and macroscale systems. On the other hand, environmental SEM (ESEM) allowed us following the flow of liquids with improved time resolution (ca. 1 frame/10s), without much compromise in spatial resolution (tens of nm). We found, however, that beam damage limits the use of ESEM especially for biomolecular systems.

References

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[3] A. Fang, E. Dujardin, T. Ondarçuhu, Nano Letters **10** (2006) 2368
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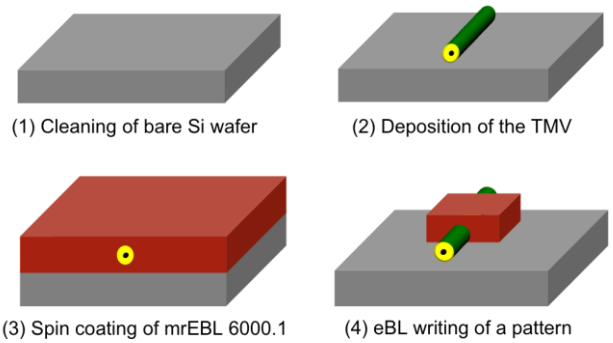
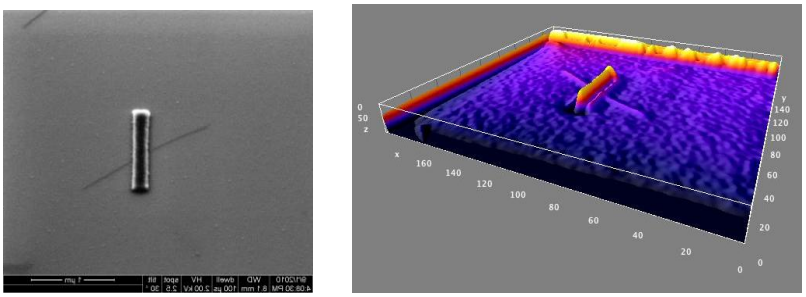
Figure 1

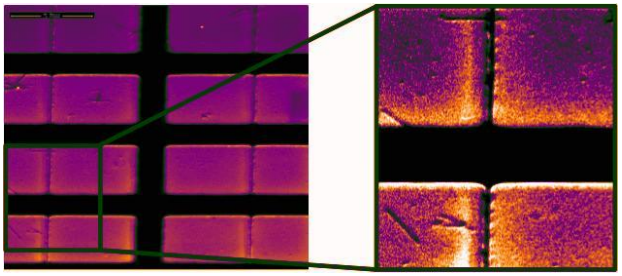


Virus nanotube immobilization through negative resist mrEBL6000.1 (fabrication)

Figure 2



TMV particle covered by a rectangular block of polymer resist (mrEBL6000.1). Image size: 3.7x3.4 µm



TMV particles inside a polymer resist grid (PMMA). The particle at the bottom can be separately addressed by two liquid containers (left and right). Grid size: 4.1x2 µm