

Viruses rise to the surface

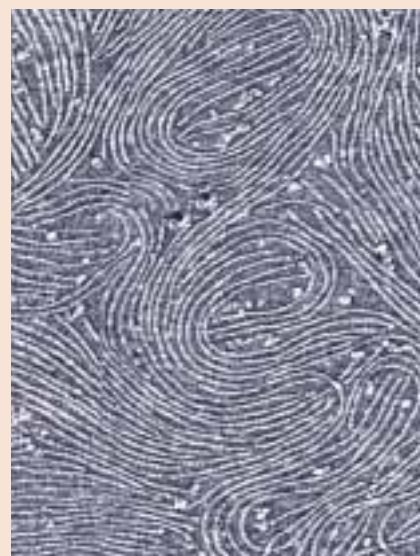
NANOTECHNOLOGY

Massachusetts Institute of Technology researchers have managed to drive the formation of an ordered layer of viruses on top of a polymer thin film [Yoo *et al.*, *Nat. Mater.* (2006) **5**, 234]. The two-dimensional, liquid crystalline layer of virus particles can be used as a scaffold for the nucleation of inorganic nanostructures. The result is an assembly strategy for creating hybrid thin films for applications in sensors, power devices, and catalytic reactive membranes.

Layer-by-layer assembly uses the alternate adsorption of oppositely charged polyelectrolytes to build up thin films. Where there is strong binding between the polyion pairs, the resulting polyelectrolyte multilayers (PEMs) tend to be kinetically frozen, ionically crosslinked networks. But pairs of weak polyelectrolytes allow rearrangements or interdiffusion of the species during absorption. Paula T. Hammond, Angela M. Belcher, and colleagues used such a pair of weak polyelectrolytes, linear-polyethylenimine (LPEI) and polyacrylic acid (PAA), and added in M13, a rod-shaped negatively charged virus. Beginning with a thin PEM with a positively charged LPEI top layer, M13 viruses randomly deposit on top. Subsequent deposition of further

PAA/LPEI layers forces the virus and PAA to compete with each other in the formation of electrostatic interactions with LPEI. Since PAA forms stronger interactions, and because the polyelectrolytes can diffuse within the multilayer, the viruses are displaced and driven to the surface.

"Remarkably, the virus layer rises to the top surface, regardless of the number of polymer layers adsorbed on top," says Hammond. Here, repulsion between the closely packed viruses results in liquid crystalline ordering. The viral layer can be used to nucleate inorganic crystals or bind nanoparticles to give hybrid monolayers on free-standing polymer films. Cationic nanoparticles can be bound directly through electrostatic interactions, or peptides can be incorporated into the virus by genetic engineering to bind specific inorganic materials. The low cost of this method, coupled with the variety of inorganic materials that can be deposited, should lead to a number of technological applications, say the researchers. "Because biological or electrochemical function can be incorporated, and the process is scalable, it opens the door to the development of free-standing thin films or coatings for large-scale devices on fibers or fabrics," explains Hammond.



Atomic force micrograph of an ordered monolayer of M13 viruses on a PEM surface. (Courtesy of Paula Hammond.)

The group is currently developing thin-film electrode materials on ionically conductive multilayers to construct lightweight and flexible Li ion batteries.
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DNA attached to single pores for biodetection

FABRICATION & PROCESSING

Researchers at Lawrence Livermore National Laboratory have drilled single nanopores into Si films and functionalized the opening so that they can detect biomolecules and cells as they pass by [Nilsson *et al.*, *Adv. Mater.* (2006) **18**, 427].

The principle that the ionic current passing through a single aperture drops every time a cell flows through and obstructs the channel has been used for many years to count cells. Reducing the aperture size allows smaller and smaller biological objects to be detected in the same way, but local chemical functionality at the pore is required to be able to detect and count specific molecules or viruses. Sonia E. Létant and coworkers have developed a method to achieve this that creates pores with sizes from the micrometer to nanometer range with openings that are derivatized with short, single-stranded DNA molecules.

A 700 nm thick silicon-on-insulator (SOI) wafer is coated with 100 nm of Si_3N_4 . A focused ion beam (FIB) is used to drill a nanopore in the wafer, which can be tens of nanometers in diameter or up to several micrometers in size depending on the Ga^+ ion beam current and drilling time. The pore can therefore be tailored to the size of different biological objects from DNA to bacteria.

Controlled growth of a SiO_2 ring around the pore is possible through FIB-assisted deposition. A precursor gas, consisting of tetraethylorthosilicate gas and water vapor, is introduced in to the chamber and the ion beam is focused to where deposition is to occur. The secondary electrons generated by the FIB decompose the precursor gas, resulting in local deposition of SiO_2 . The SiO_2 rings can then be derivatized with thiol linkers, to which DNA probes are attached.

The Si membrane containing the single nanopore is placed between two cells containing KCl solution, and the ionic current recorded. Current-voltage measurements can be correlated with the pore size, and the change in ionic current on functionalization with DNA determined. In this way, the researchers confirm the presence of DNA at the pore, and that the pore remained open.

"Our next step will be to demonstrate that the transit time of functionalized beads through the pores provides information on the chemical affinity between the pore and bead surfaces," Létant told *Materials Today*. "If specific ligands are anchored on the pores, this mechanism could be used to create electrical fingerprints for viruses or bacteria and potentially provide crucial information on unknown organisms."

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