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METALLIZATION OF THE OUTER AND INNER SURFACES OF A PLANT VIRUS

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INTRODUCTION: Electroless deposition from metal ion solutions yields metal structures on and inside the Tobacco Mosaic Virus (TMV). Coatings, clusters and 3 nm wide nickel and cobalt wires were obtained. Adsorption, covalent binding and MicroContact Printing (μCP) of pure TMV were investigated with atomic force microscopy (AFM) for a range of crystalline oxide and metal surfaces.

METHODS: Electroless deposition is a process by which metal ions, e.g. Ni(II), in aqueous solution are reduced by molecules such as hypophosphite or borane. This process is catalyzed ("activated") by noble metal nanoclusters, e.g. Pd, and thus starts at nanocluster nuclei. This cluster is formed on an organic surface from a solution of the respective ion (e.g. Pd(II)); various interactions such as electrostatic binding and complex formation come into play.

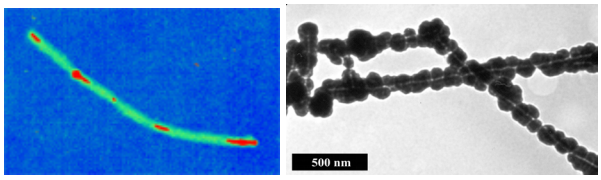

Fig. 1: Transmission electron micrographs of two tubular viruses (each 300 nm long) with five 3 nm Pd/Ni clusters in the inner channels. Right: Metallization of the exterior surface by Pt/Ni.

This "bottom-up" process of nanofabrication is ideally complemented by "top-down" μCP with a (sub)micrometer-patterned stamp: The stamp is inked with a virus suspension, and TMV is then transferred to a surface in the desired pattern. The adsorption properties of TMV were tested for a range of pH values and surfaces. Monitoring by AFM was conducted in noncontact mode.

RESULTS: The electroless deposition occurs selectively on the nanoclusters. In this way metal/metal core/shell clusters such as Pd/Ni were positioned on the tube-shaped virus particles (Fig. 1). The presence of hydrophilic groups, but also complex formation with Pd(II) and Pt(II) allowed producing clusters and wires even *inside* a nanotube, i.e. in the 4 nm wide inner viral channel (Fig. 1). With strong reductands, Ni and Co wires of only 3 nm diameter, but several 100 nm length formed (Fig. 2).

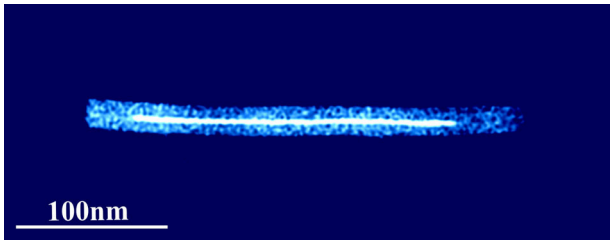

Fig. 2: Transmission electron micrograph of a 300 nm long virus with a 150 nm long and 3 nm wide Co wire (white) in the inner channel.

Adsorption and μCP (Fig. 3) showed that TMV can be immobilized by hydrogen bridges, or by covalent binding on reactive monolayers. On graphite it adsorbed only weakly by van der Waals interactions.

DISCUSSION & CONCLUSIONS: Bio-metallization of a viral nanotube is an elegant way to build nanostructures like aligned clusters and wires whose optical and magnetic properties are of great interest. A combination with spatially selective transfer by soft lithography should allow placing virus/cluster composites on a surface with nanometer precision.

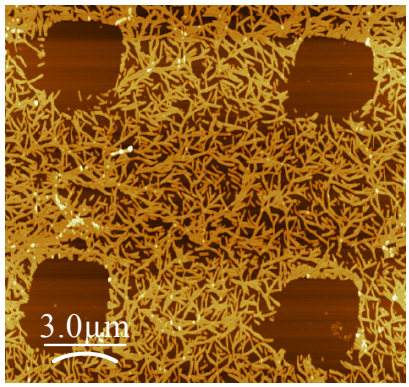

Fig. 3: Atomic force microscopy of a virus pattern (yellow) printed on a silicon wafer.