

Bio-inspired multilayered hybrid organic-inorganic composites investigated by (S)TEM

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Bio-inspired synthesis of hybrid structures consisting of organic and inorganic components at mild temperatures corroborates many advantages for applications in bio-nanotechnology. Organic components serve as templates for inorganic materials, which results in a wide range of applications in the emerging fields of organic electronics and photonics [1]. The nucleation and consequent growth of organic-inorganic nanostructures will be provoked by numerous mechanisms where the organic component is considered as a scaffold [2]. Wild-type (WT) M13 phages are commonly used as a matrix for tissues engineering and as biological templates for functional materials design. Their elongated shape and unique capability of self-assembling into liquid crystal structures offer modifiable surfaces for the construction of hybrid nanostructures.

In our study M13 phages were employed as scaffolds for engineering layer-by-layer structures composed of alternating M13 and ZnO layers. An in-house build apparatus was used to construct directionally oriented phage layers deposited on C-coated Si wafers. Based on our previous work, an amorphous carbon (a-C) offers beneficial effects for directional alignment of the M13 phages [3,4].

Advanced imaging and analytical scanning transmission electron microscopy (STEM) methods were used to study the microstructure and chemical identity of cross-sectional lamellae of a multilayered sample consisting of alternating five thin layers of M13 phages and five ZnO layers that were assembled on an a-C sputtered Si substrate. A relatively homogeneous organic-inorganic multilayered structure with only negligible thickness fluctuation and with limited interpenetration at the M13-ZnO interfaces was obtained. With our work we have paved the way for future bio-templated organic-inorganic multilayered structures with controlled and properly adjusted ratios between organic and inorganic components.

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[2] M Habib et al., *Life Robotics* **17** (2012), 191-196.

[3] P Moghimian et al., *Langmuir* **30** (2014), 11428-32.

[4] P Moghimian et al., *Int J of Mater Research* **107** (2016), 295-299.

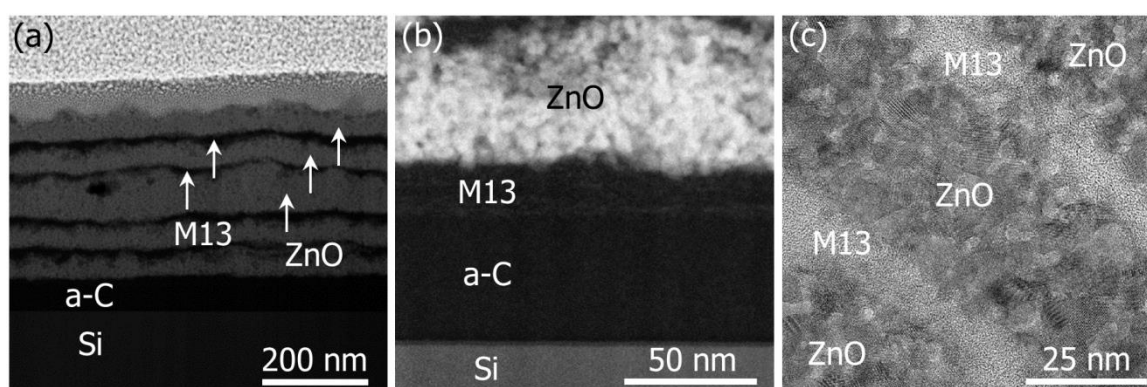


Figure 1: (a) HAADF-STEM image of a cross-section of the organic-inorganic multilayer consisting of alternating M13 phage and ZnO layers deposited on an a-C sputtered Si substrate. (b) Magnified HAADF-STEM image of the first M13 layer followed by a ZnO layer. (c) HRTEM image of M13 layers between ZnO layers.