

Metal incorporation in block copolymer templates

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Abstract

Metal nanostructures exhibit a wide range of size-dependent properties and variations in fundamental characteristics, ranging from optical properties [1] to electrical conductivity [2], which can be tuned by controlling the nanostructure architecture. In order to integrate metal nanostructures in a form suitable for applications, it is necessary to control the alignment and size of metal nanoparticles on a substrate. Block copolymer (BCP) templates have attracted much attention for the organization of nanostructures with high degree of complexity [3-5]. BCPs microphase-separate into ordered structures on a nanometre scale and are used as templates for metal nanoparticles. However, the interaction between metal nanoparticles and the BCP templates is poorly understood and is the subject of this paper.

We present a detailed structural analysis of evaporated titanium (Ti) with a nominal layer thickness of 2.5, 5.0, 7.5 nm on underlying BCP templates (**Figure 1**). The microphase separated BCP surface, with polyethylene oxide (PEO) cylinders imbedded in a polystyrene (PS) matrix, act as a directing agent for the evaporated titanium atoms. Using a low evaporation rate, titanium atoms preferentially cover the PS part of the BCP film (**Figure 2**). X-ray reflectometry (XRR) measurements revealed that titanium also accumulates inside the BCP film (**Figure 3**). Upon further deposition, a continuous titanium layer forms on the PS matrix, which prevents the further introduction of titanium in the BCP film. We performed grazing incidence small angle X-ray scattering (GISAXS) synchrotron experiments, which enabled us to correlate the titanium morphology with the buried polymer structure (**Figure 4**). We could show that the titanium layer forms a mesoporous structure with a periodic pore-to-pore distance of 37 nm, resulting from the underlying PEO cylinder periodicity.

The combination of GISAXS and XRR points out to be crucial for the understanding of how titanium nanoparticles integrate in PS polymer domains. Our results introduce the concept that titanium accumulation is not limited to the flat polymer surface, but also includes in the matrix of insulating polymer bulk material.

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References

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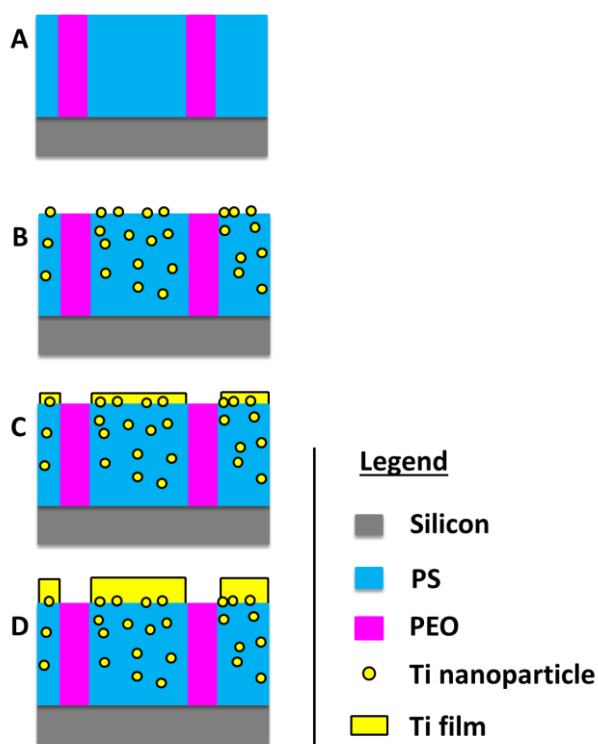


Figure 1: Schematic cross section of the sample preparation. A microphase separated BCP film (A), forming PEO cylinders in a PS matrix, was used as a template and coated with Ti by evaporating nominal 2.5 (B), 5.0 (C) and 7.5 nm (D) on the template.

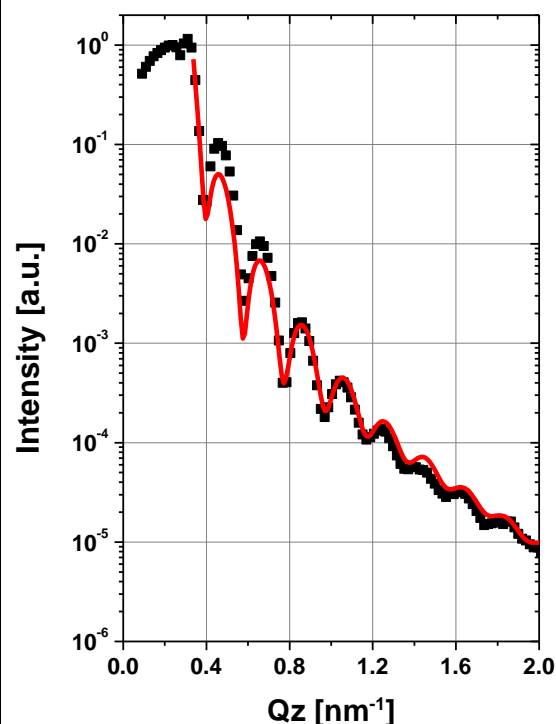


Figure 3: X-ray reflectivity data (black dots) of the sample with nominal 2.5 nm Ti on a BCP template. A corresponding fit is shown as a red line.

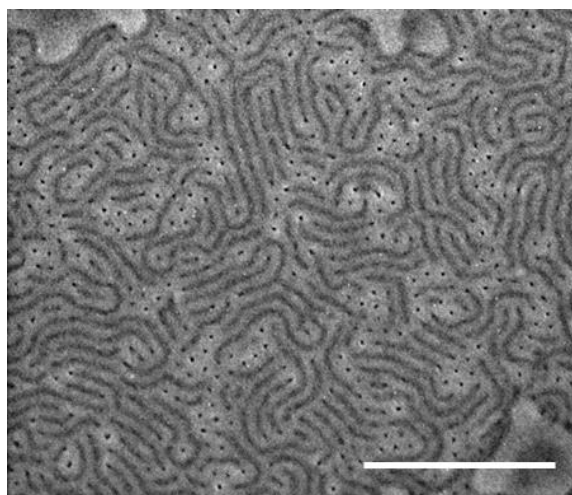


Figure 2: SEM image of a BCP film after evaporation of Ti with a nominal layer thickness of 7.5 nm. The lighter areas represent the PS block with Ti coating and the darker areas the PEO block of the microphase separated BCP. The scale bar corresponds to 500 nm.

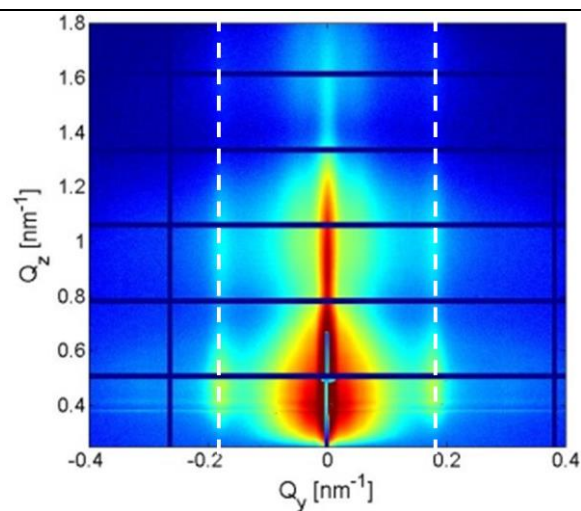


Figure 4: 2D GISAXS map of. The diffraction peaks, indicated by white dashed lines, are the result of the periodic Ti pore-to-pore distance of 37 nm.