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Short Communication

Self-organized organic nanostructures: structure formation in thin polymer blend films

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Sharp-edged and well-defined micro- and nanostructures can be produced by a simple spin-coating process of a polymer solution.[1]

Dissolving two incompatible polymers in a common solvent and spin-coating the solution will lead to phase separation during evaporation of the solvent. The morphology of the two coexisting phases can be organized normal or

parallel to the film surface, depending on the surface energy of the substrate. By using chemically heterogeneous pre-structured substrates, made by micro-contact printing, any pattern can be used to induce a compositional variation in the polymer film (see Fig. 1). Thus, by controlling the phase morphology, one can create surfaces with new properties so that those systems are applicable for lithography masks, optical components or biological sensors.

In addition, a laterally isotropic phase separation can lead to new physical properties. For instance, if we remove one of the two polymers having a morphology with a lateral

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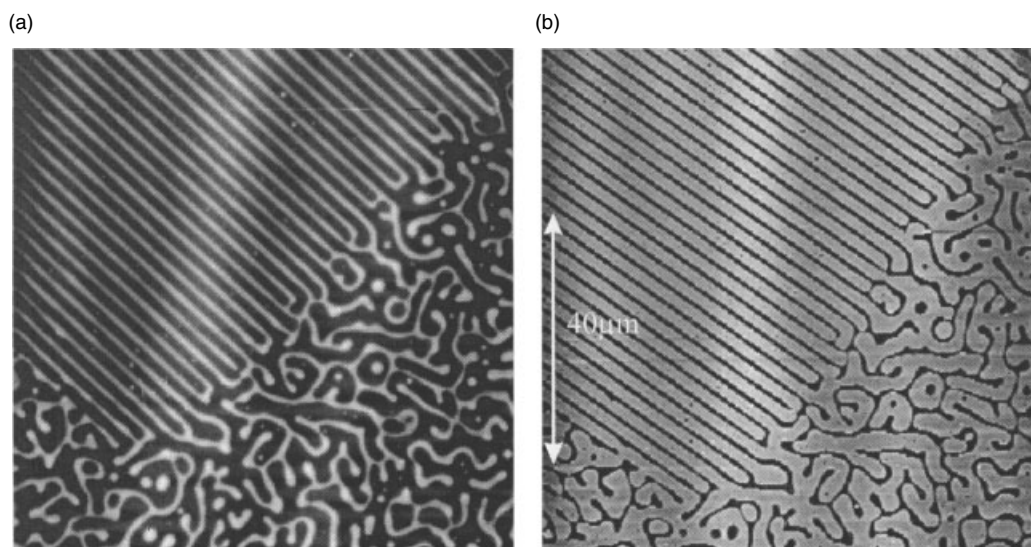E-mail: stefan.walheim@int.fzk.de

Figure 1. Atomic force micrographs of a polystyrene (PS)/polvinylpyridine (PVP) blend (50/50 wt.%) spun-cast from a tetrahydrofuran (THF) solution (1.5 wt.% polymer) onto a patterned gold substrate. To create a surface with laterally varying surface energies, micro-contact printing technology (with octadecylthiol molecules) was used. The sample is shown as cast in (a) and after removal of PVP by dissolution in ethanol, in (b). Image (a) exhibits a surface corrugation that is perfectly aligned in a grid pattern. The topographic undulation originates from a lateral organization of the polymer phases. This is demonstrated by immersing the sample in ethanol which is a selective solvent for the PVP phase and hence removes it. The remaining PS domains (b) show a remarkable contrast in the AFM image (stripes with a rectangular cross-section). The polymer domain morphology in (a) is due to the strong affinity of the PVP to the more polar gold surface, displacing the PS towards the parts of the substrate that are covered by the self-assembled monolayer (SAM). The perspective representation (c) shows the rectangular cross-section of the 65 nm high PS stripes in (b). Dark grey areas in (c) indicate the SAM-covered substrate regions. On the bottom part of (a) and (b) where the substrate is completely SAM covered, a disordered structure is obtained. The perfect replication process extends over much larger length scales than shown in the atomic force micrographs and is limited only by the sample size. A plexiglass disc covered with a nanophase-separated polymer film, which acts as an antireflection coating, is featured in (d). Only the lower left part of the disc is coated.
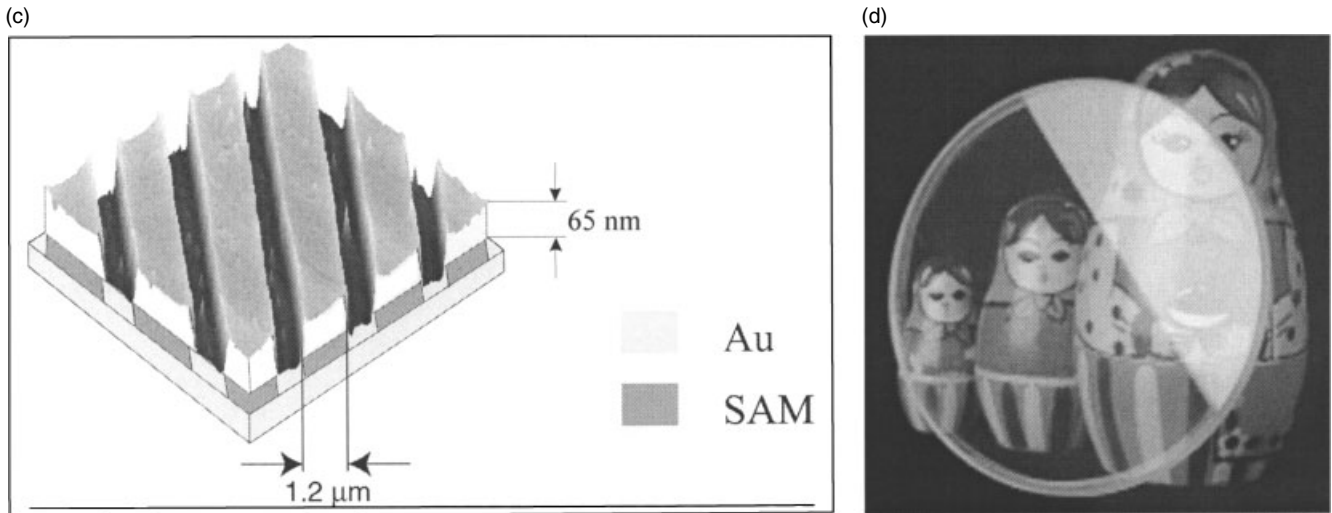
(c)

(d)

Figure 1. (*Continued*).

length scale below 200 nm, we are left with a nanoporous film that can be used as a high-performance antireflection coating (Fig. 1(d)).[2,4] The refractive index of our films can be adjusted in a range from 1.6 down to 1.05 by tuning the composition of the polymer solution.

As shown in Refs 1–6, the natural lateral length scale of the phase separation can be adjusted down to 150 nm. By using block-copolymers (molecules that consist of two or more blocks of different polymers) even smaller correlation lengths (20–10 nm) can be realized. In our present work we are trying to produce ordered structures with this periodicity.

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