Electrically-assisted nanoimprint of block-copolymers

A. Mayer, W. Ai, J. Rond, J. Staabs, C. Steinberg, M. Papenheim, H.-C. Scheer
Microstructure Engineering, University of Wuppertal, 42119 Wuppertal, D
amayer@uni-wuppertal.de

M. Tormen[a)b)], A. Cian[a)]
[a)]ThunderNIL, 35131 Padova, [b)]IOM-CNR Area Science Park, 34149 Trieste, I

J. Zajadacz, K. Zimmer
Leibniz Institute of Surface Modification, 04318 Leipzig, D

The phase separation of block copolymers (BCP, block ratio 1:1) under assistance of an electric field during thermal nanoimprint (ET-NIL) is investigated with a lamella-forming PS-PMMA BCP. Lamella perpendicular to the substrate are aimed to serve as a mask for patterning of the substrate [1]. To simplify the process, working without a neutral brush is attractive. In such a case electric fields may help to ensure a vertical orientation [2]. It is reported that a minimum field strength of about 12 V/µm in the BCP layer is required to overcome the surface energy of the substrate with a cylindrical BCP [3]. However, guidance is still required to provide a well-ordered structure.

Our idea is to guide the phase separation by nanoimprint. This has the benefit that the stamp applied for guiding can be used several times, avoiding laborious pre-preparation of every substrate, as it is the case with grapho- or chemo-epitaxy. We recently could demonstrate that it is possible to imprint a lamellar PS/PMMA block copolymer and to achieve ordered vertical lamella [4], even with a preferential substrate. Now the question is, to which extent the results can be improved when an electric field is present simultaneously.

An imprint without residual layer is envisaged; thus, in order avoid a short cut we use a stamp with SiO_2 structures and a substrate with an oxide layer on top. Fig. 1 displays the situation during the imprint of the BCP-layer. With an electric field applied all dielectric elements represent capacitors. The capacitors in the central part, where the BCP is located, change their magnitude during imprint as documented in Fig. 2. In particular, the capacitor representing the BCP in the cavity is infinite at the beginning and drops; the one beneath, representing the continuous, residual layer of the BCP, goes to infinity when the layer is imprinted through. Our experimental setup is shown in Fig. 3. The electric field is applied between the two electrodes as indicated. Fig. 4 documents that the concept works: the electric field improves the phase separation.

We investigate whether the strength of the electric field reported [3] to overcome the surface energy can be adopted for ET-NIL and if the degree of order obtained with higher layer thickness can be actually improved compared to earlier results [4]. Most important for technical application, we will check the potential of an electric field to shorten the process time.

[1] J. Zajadacz at al, Microelectron. Engin. 141 (2015) 289
[2] K. Amundson et al, Macromolecules 24 (1991) 6548; T.L. Morkved et al, Science 273 (1966) 931; J. DeRouchey et al, Macromolecules 37 (2004) 2538
[3] T. Thurn-Albrecht et al, Macromolecules 33 (2000) 3250
[4] A. Mayer et. al., Microelectron Engin. 176 (2017) 94

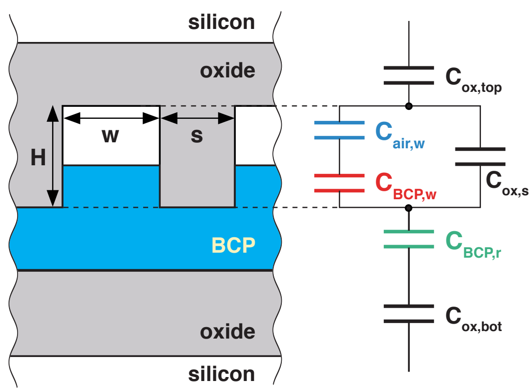

Figure 1. Configuration during imprint of the BCP layer and respective capacitors. The elements changing during imprint are colored. (Anneal with phase separation after imprint.)

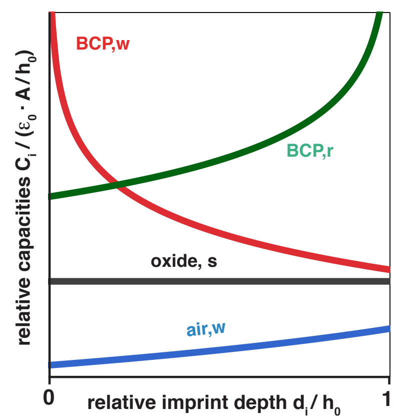

Figure 2. Caculated relative capacitance values with onging imprint, normalized. The imprint depth increases from zero to the initial layer thickness.

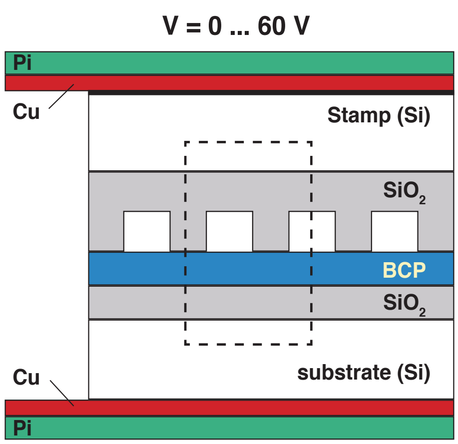

Figure 3. Experimental setup used for electrical field assisted thermal nanoimprint (ET-NIL).

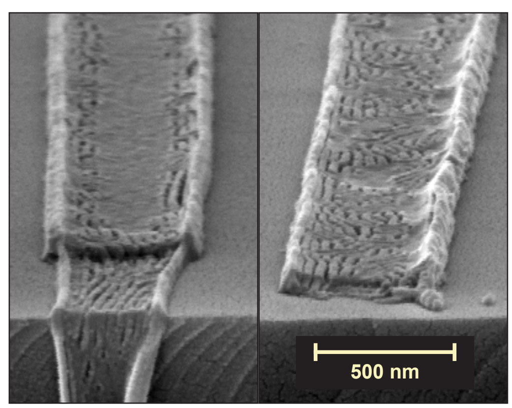

Figure 4. Phase separation in a cavity with (right) and without (left) an electric field.