Procedure for high temperature nanoimprint of organic semi-conducting polymer

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Due to easy fabrication and low costs, semi-conducting polymers are of increasing interest for the electronics industry. However, they feature electrical anisotropy[1]. With respect to devices, a control of the preferred direction of conductivity is beneficial, which may be obtained by patterning. Typically, these polymers are semi-crystalline and can be deformed under temperature[2]. Therefore, thermal nanoimprint is an excellent candidate for structuring these polymers and for re-defining the preferred direction of conductivity. For re-defining conductivity the crystallites already existing after spin-coating have to be melted, which requires a relatively high temperature during imprint, – other groups[3] restricted their imprint experiments to temperatures below the melting point. This limitation of the imprint temperature may result from the fact that the organic polymers degrade[4,5] at high temperature during a standard T-NIL procedure. On the other hand, Chen et al.[6] revealed that organic conducting polymer withstand high temperatures in an inert atmosphere without degradation – P3HT still re-crystallized after annealing at 300 °C under argon. This gives us a hint how to proceed in order to avoid degradation at high temperature, even without a high-cost imprint system operating in an inert atmosphere.

To reduce oxygen exposure during imprint we propose a novel procedure, heating under pressure. Fig.1 compares the standard procedure (low contact pressure during the heating step) and the new procedure. For our investigation we used P3HT as organic conducting polymer and imprinted with an OrmoStamp stamp as shown in Fig 2. With P3HT, the color is a direct indicator of degradation – the original color is purple. Fig. 3 shows that after the standard procedure the color is orange, indicating degradation, whereas with the new procedure, the original color in the contact area to the mold remains. Furthermore, polarized transmission spectrometry (Fig.4) indicates that a high conjugation length only remains after heating under pressure.

We will investigate which pressure level is required during heating to efficiently avoid degradation. Pressure minimization is advised to avoid stamp damage during the heating step.

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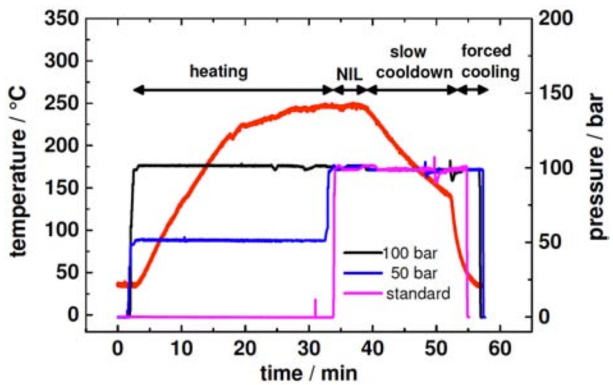

Figure 1: Procedure scenarios. Heating of imprint stack to the process temperature (red) either a) under low contact pressure (standard), b) under intermediate pressure (50 bar) or c) under process pressure (100 bar). Imprint time 5 min. Slow cooldown to about 150 °C for recrystallization. Forced cooling (water) to room temperature.

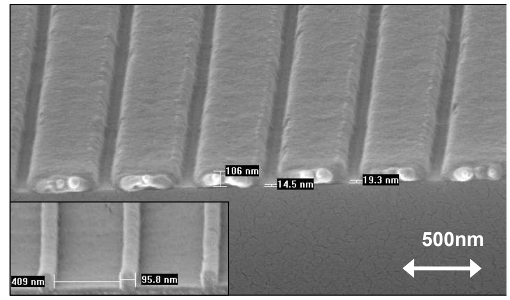

Figure 2: Cross section of imprint result obtained with P3HT (initial layer thickness: about 100 nm; substrate: borofloat glass).
Inset shows the imprint mold (20 um OrmoStamp Microresist, Berlin´ on borofloat) with lines of 75 nm width and 500 nm pitch.

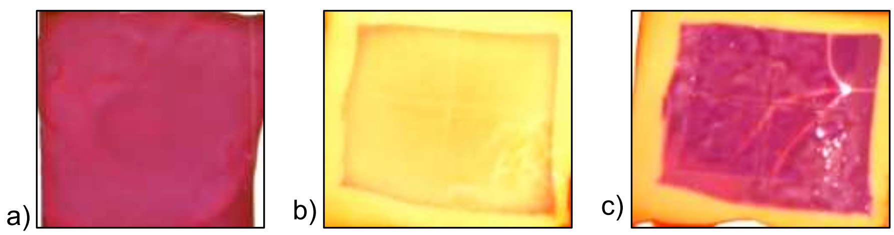

Figure 3: Photographs of P3HT on borofloat after spin-coating (a) and after imprint following the standard procedure (b) and following the new procedure (c). The new procedure avoids degradation in contact areas (intact material: purple; degraded material: yellow).

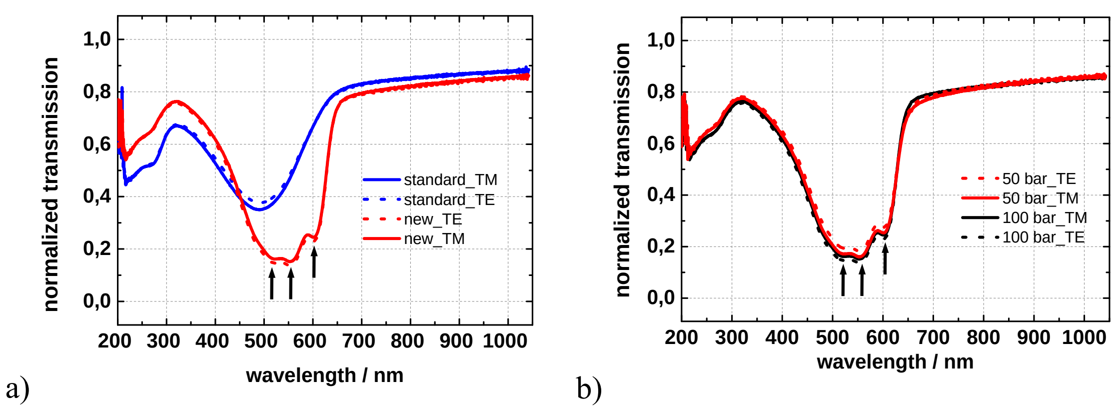

Figure 4: Characterization by transmission measurements. a) The new procedure avoids degradation, characteristic peaks (long conjugation length[6]) remain. b) Reduced pressure (50 bar) is already sufficient to maintain material integrity with new procedure.