Viscoelastic properties measurements of thin polymer films from reflow of nanoimprinted patterns

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Surface dynamics of viscous polymer films has been widely studied for fundamental purposes, as well as for applications such as NanoImprint Lithography (NIL). Despite a huge experimental development of imprinting equipments, stamp manufacturing processes, imprint processes, dedicated materials and metrology approaches, a complete simulation toolbox of NIL is still lacking. Among remaining issues, complex mechanical stamp deformations as well as fluid flows [1] have to be considered, adhesion and friction mechanisms during stamp demolding should be also introduced and flow properties of melted resists within nanometric cavities should be currently implemented in NIL modelling.

We describe in this paper a fast and cost-effective method to measure the viscoelastic properties of a thin polymer film from the reflow of nanoimprinted patterns. As depicted on figure 1, the polymer is spin-coated onto a silicon substrate (1a) and a specific patented pattern is imprinted using thermal NanoImprint (1b). A first measurement of the imprinted profile is done by AFM (1c). The film is then heated at a definite temperature above the glass transition temperature during a definite time (1d). The film is rapidly cooled down and the reflowed profile is again measured by AFM (1e). Spectral densities of the profiles are computed using standard Fourier transform algorithms, and the viscoelastic properties are computed as fitting parameters of an evolution model for the spectral density of the topology. Using our approach, we measured the viscoelastic properties (η and E) of 150nm-thick polystyrene 30k films, assuming a simple Maxwell model [2]. Both initial and annealed topographies are shown in figure 2. Figure 3 reports the damping factor of each frequency, and two models are fitted to the experimental data. Parameters of any kind of linear law for the viscoelastic behaviour of the material such as (generalized) Maxwell model or Burgers model can be computed using our method.

[1] Leveder T., Landis S., Davoust L., Reflow dynamics of thin patterned viscous films, Appl. Phys. Lett. 92, 013107, 2008.
[2] Ferry J.D., Viscoelastic properties of polymers, John Wiley & Sons Inc. 1980.

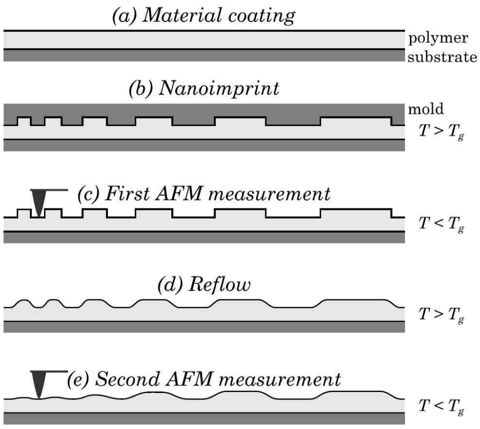

Figure 1: Main steps of the viscoelastic properties measurement method.

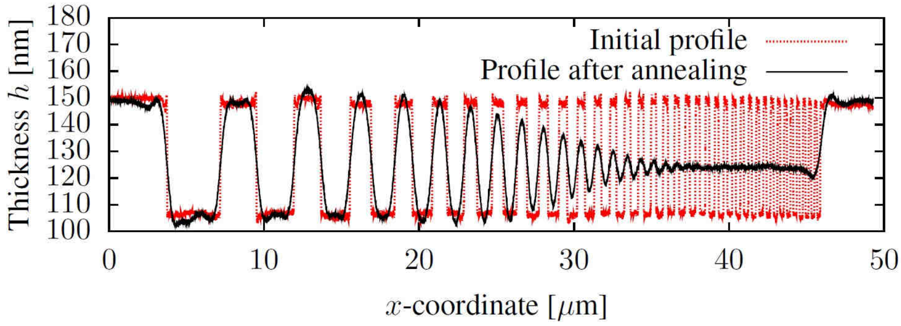

Figure 2: AFM profile of an as-imprinted pattern in a polystyrene film (dotted line) and after annealing (solid line) 5 min at 120°C.

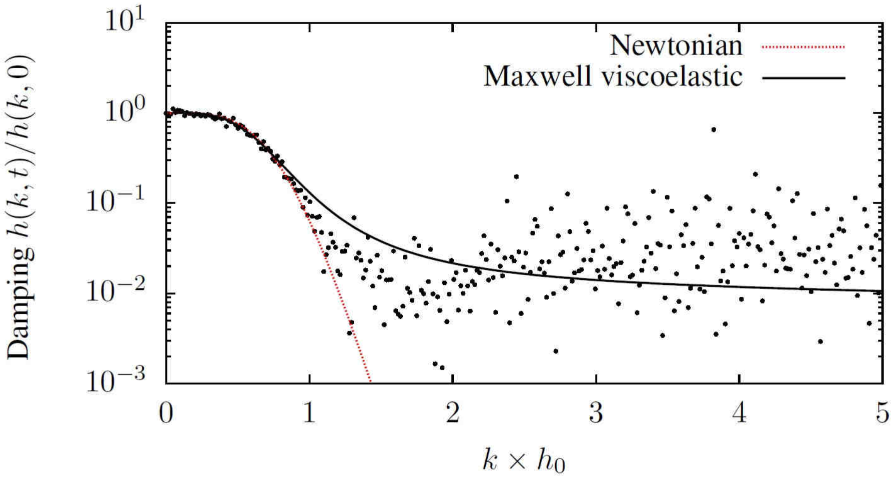

Figure 3: Damping factor of the topography as a function of wavevector (spectral modes). Points are experimental data computed from figure 2, compared with a purely viscous Newtonian model (dotted line) and a viscoelastic Maxwell model.