Viscosity measurement of NIL resists with rheological nano–indenter.

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Nanoindentation is widely used for characterization of mechanical properties of different materials at micro/nanoscale. Many efforts were devoted to elaboration of approaches for measurement of elastic properties (Young module) of local area under indenter tip. Nanoimprint lithography (NIL) attracts attention to inelastic behaviour of resist under imprint and to another mechanical property of a material, to viscosity. Usually consideration of elastic interaction of the tip and a sample (Hertz problem) is used for measured data interpretation what is not valid for viscous penetration of the tip into the sample.

The report is devoted to description of new approach for determination of viscosity with nano-indenter. Considering Navier-Stokes equation a problem of penetration of a tip of *given shape* was solved in manner allowing acquisition of viscosity η from experimental data

$$\frac{1}{h} = \frac{8pR_0^2}{\int dtF(t)}\left(\frac{z}{H_0}\right)^3$$

R is a local tip radius, z is a inelastic penetration (residual penetration), H_0 is a resist thickness. $F(t)$ is tip force depending on time. In-house fabricated rheological indenter and its control system allows to measure z and to accumulate force $F(t)$. For tip of spherical shape viscosity could be expressed directly according to relation

$$\int dtF(t) = h\left\{2 - \ln\left[\left(1-\frac{z}{H_0}\right)\left(1+\frac{z}{H_0}\right)^3 - \frac{2}{1-z/H_0}\right]\right\}pR^2\frac{2}{3}$$

The rheological indenter allows measuring at varying temperature so it is possible to measure the viscosity as function of temperature in range 25-200C.

The approach was practically applied for measuring viscosity of PMMA films (200-300nm) of different molecular weight. Expected decreasing of viscosity with decreasing of molecular weight was observed, quantitative dependence is discussed showing good correspondence to theory.

First results of backing kinetics measurements are shown in Figure 2 demonstrating good perspectives of crosslinking kinetics investigation for thermo- and photo-curable polymers.

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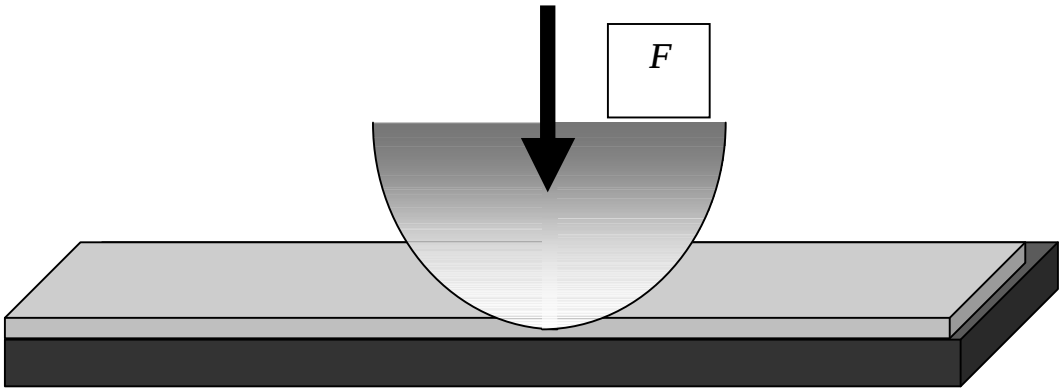

Figure 1. Tip of given shape (e.g. sphere) is indented in thin film.

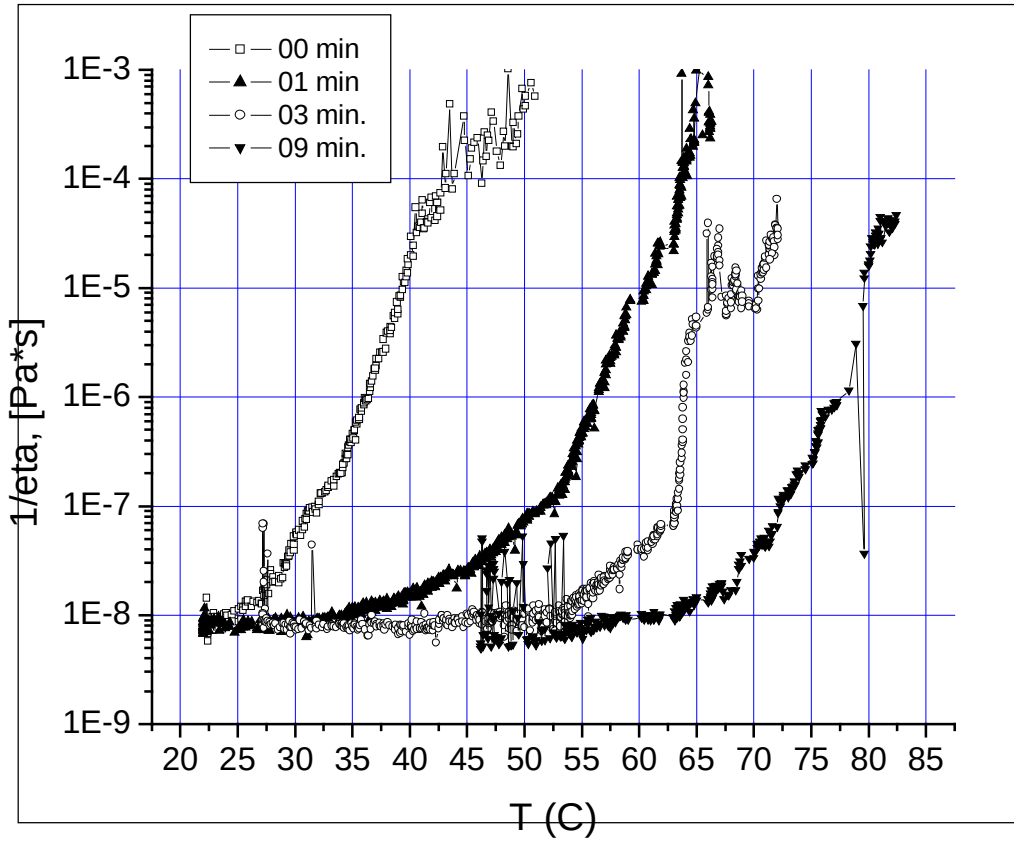

Figure 2 shows example of viscosity measurements for epoxy sample subjected to backing at 170 C for different times (0, 1, 2,4, 8min).