

Stress and aging minimization in photoplastic AFM probes

Cristina Martin^{a,b}, Andreu Llobera^a, Guillermo Villanueva^b, Anja Voigt^c, Gabi Gruetzner^c, Juergen Brugger^b, Francesc Pérez-Murano^a

^a CNM-IMB-CSIC Barcelona, 08193, Spain

^b EPFL, Microsystems Laboratory, Lausanne, CH-1015, Switzerland

e-mail: Cristina.Martin@epfl.ch

^c Microresist technology GmbH Berlin, D-12555, Germany

In this work it is shown that by appropriate hard bake the built-in stress in negative tone epoxy based resists, like SU-8, can be considerably reduced which turn improves the materials properties such bending and aging and makes them good candidates for the low cost fabrication of micromechanical systems and devices (MEMS). For instance, fabrication of AFM probes has been recently proposed [1, 2]. Epoxy based resists are soft materials with a Young's Modulus around 4 GPa, which makes them particularly suitable for non-destructive AFM analysis on fragile samples such biological materials [3]. On the other hand, this also implies a larger deflection due to internal gradient stress as compared to conventional, stress-free, single-crystal silicon probes. This is critical because useful AFM probes must present cantilever bending below 1° angle deflection at the tip. Hence, it is ensured that the reflection of the laser will be collected by the photodiode. In addition, this small deflection angle must be stable over a long time, which is another drawback of photoplastic devices.

It has been observed that the material properties of the epoxy based resists strongly vary with variations of the process parameters [4]. Concretely, it has been observed that in absence of Post-Exposure Bake (PEB), photoplastic structures swell when exposed to humidity, which is accompanied by a variation of its mechanical properties. Therefore, an optimized fabrication process is proposed that allows to minimize the stress in the cantilever layer and to improve their shelf life-time. The difference presented consists basically in the specific hard bake step. Generally, a hard bake step further crosslinks the material and minimize stresses and cracks. Hard bake optimal conditions (time and temperature) have to be found depending on the film thickness, resist and even exposure time. Three different hard bake processes have been tested. All three different hard bake processes were performed on a hot plate, from 21°C to the set temperature and in a saturated N₂ environment. These processes do not present any drawback, being a very cost-effective and reproducible solution. In addition to the bending tests, a systematic aging study has been done to check the actual deflection angle of these probes and to test their feasibility as a commercial product.

The results for the hard bake process show a significant reduction of the undesired deflection angle, allowing all the fabricated and released AFM probes utilizable for commercial AFM systems (Figure 1). In addition the 1-year aging study assures the maintenance of the deflection angle in time (Figure 2).

The fabricated AFM probes have demonstrated a good operation for imaging in dynamic AFM mode. Although Q factor have not been increased due this hard bake process, as the cantilevers can be fabricated with a very low resonance frequency, they also can work in their second resonant mode. The second resonance mode has a higher Q factor (Figure 3) and a higher protection between the sample and the tip due to the fact that the force applied while scanning is significantly reduced. The operation in the second harmonic makes their performance comparable to standard silicon probes (Figure 4).

This work is partially funded by the EU project NOVOPOLY under contract number STRP 013619.

- [1] G. Genolet; J. Brugger; M. Despont; U. Drechsler; P. Vettiger; N. F. de Rooij; D. Anselmetti. Review of Scientific Instruments (1999), 70, 2398-2401.
- [2] G. Genolet; M. Despont; P. Vettiger; D. Anselmetti; N. F. de Rooij. Journal of Vacuum Science & Technology B (2000), 18, 617-620.
- [3] H. Lorenz; M. Laudon; P. Renaud. Microelectronic Engineering (1998), 42, 371-374.
- [4] A. Llobera; V. Seidemann; J. A. Plaza; V. J. Cadarso; S. Buttgenbach. Journal of Microelectromechanical Systems (2007), 16, 111-121.

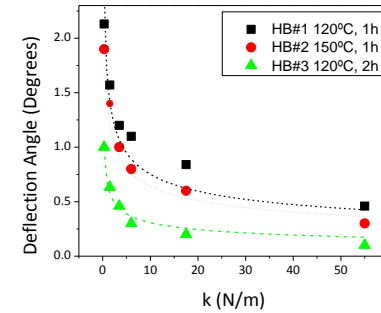


Figure 1. Deflection angle dependence with the spring constant. Each group of data corresponds to a different hard bake. The best process is to perform a hard bake during 2 hours at 120°C.

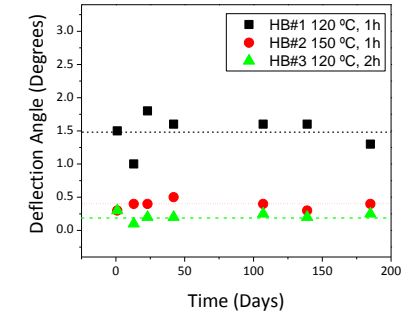
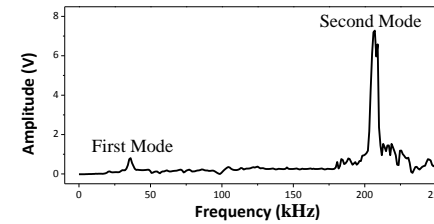


Figure 2. Aging study of the deflection angle for three cantilevers with the same spring constant (26 N/m) processed with the three different hard bakes.



Epoxy based AFM probe k = 8 N/m			
Mode	Theoretical	Experimental	Experimental Quality Factor
First	34 kHz	35 kHz	26
Second	213 kHz	208 kHz	186

Figure 3. Frequency spectrum of a photoplastic AFM probe with a spring constant of 8 N/m. The experimental values match those expected and the quality factor is increased by a factor >6.

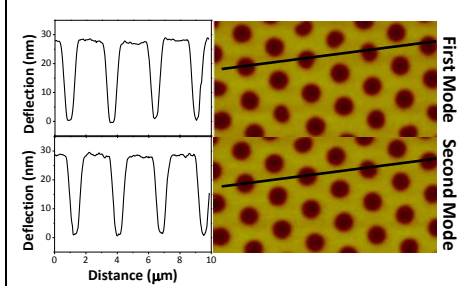


Figure 4. AFM measurements have been performed using a fabricated photoplastic AFM probes with a spring constant of 8 N/m. They have been operated in the first and the second resonant modes using a free amplitude of 250 nm and a set point of 137.5 nm for both modes. Topographic images of nano circles (700 nm diameter) patterned in silicon surface evidenced no difference between the modes.