Design and Implementation of Soft Polymer-Based Cantilever Probe for Atomic Force Microscopy

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Surface- and/or bulk-micromachined polymer-based cantilever probes have been proposed for Atomic Force Microscopes (AFMs) to enable non-destructive high-resolution topological imaging of biological samples [1-2]. Polymeric AFM probes developed to date however, consist of a rather stiff cantilever (with relatively high spring constant), which would cause deformation and distortion of biological samples while scanning, and a rather blunt probe tip, which would limit high-resolution imaging. In this work, we report a very soft AFM probe, which comprises a polymer-based V-shaped cantilever with a sharp tip at its free end. Firstly, we achieve a very low spring constant less than 0.01 N/m, which is over an order of magnitude smaller than that of the softest, commercial Si-based cantilever (~0.1 N/m), using Poly(MethylMethAcrylate) (PMMA) polymer as a structural material. Secondly, we achieve a sharp probe tip with a radius of curvature as small as ~40 nm, which is comparable to that of typical Si-based AFM probes, via sequential depositions of low-viscosity and high-viscosity PMMA. Lastly, we achieve a reasonably-flat cantilever surface with strain gradient as low as 10^{-4} /μm via proper patterning of the optical reflection coating.

Fig. 1 shows a schematic, design parameters, and scanning electron micrographs (SEMs) of the soft AFM probe of this work, which has a sharp probe tip and a visually-flat cantilever surface. **Fig. 2** illustrates a fabrication process flow; Highlights of the process are: (1) After the formation of a pyramidal pit (**Fig. 2(b)**), low-viscosity PMMA was spin-coated first to fully fill the cavity, which is the key to achieving a sharp tip. Afterward, relatively high-viscosity PMMA was spin-coated to achieve a sufficiently-thick cantilever body; (2) Au/Cr reflection coating atop the cantilever body, which is needed to reflect incoming laser light to track cantilever motion, was patterned as shown in **Fig. 2(d)** (i.e., thin Au/Cr films were added only at the tip area) in order to minimize strain gradient within the cantilever and hence achieve a flat surface. **Fig. 3** shows that a sharp probe tip is achieved by decreasing PMMA solids content, i.e., by further diluting the low-viscosity PMMA with a diluent (Anisole). **Fig. 4** shows that strain gradient is reduced dramatically by placing the Au/Cr reflection layer only at the tip area. **Fig. 5(a)** shows measured thermal fluctuations of fabricated V-shaped cantilevers of different length as a function of frequency. Spring constant (k_{eff}) of the cantilevers were extracted (**Fig. 5(b)**) by fitting a Lorentzian function to the measured frequency spectrum.

[1] J. D. Adams *et al.*, Nature Nanotechnology (2015).
[2] M. Tortonese, IEEE Eng. Med. Bio. Mag., **16**, 28 (1997).

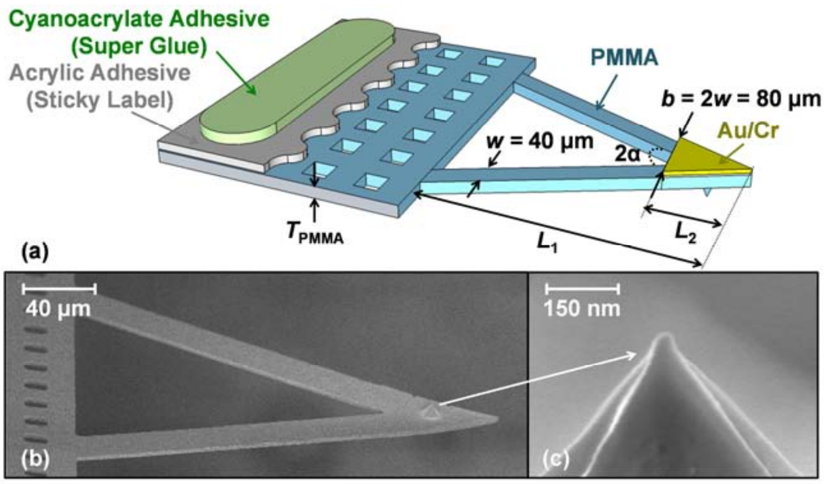

Figure 1: Schematic, design parameters, and SEMs of a soft polymer-based AFM probe.

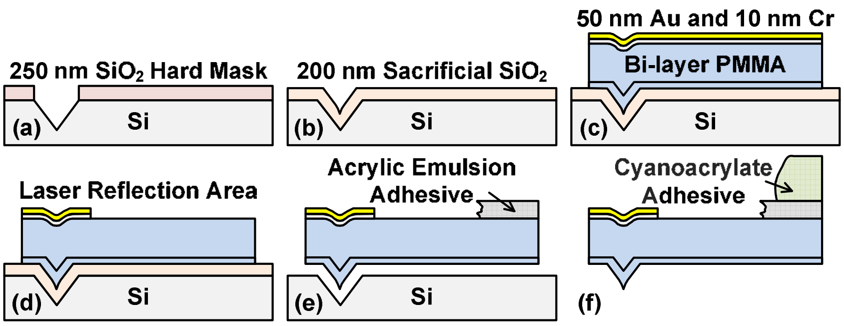

Figure 2: Three-mask fabrication process flow.

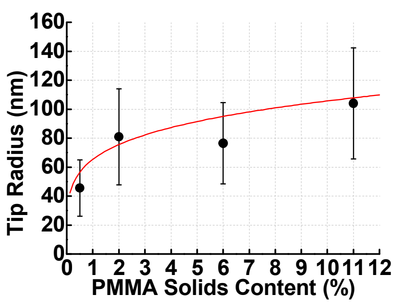

Figure 3: Measured probe tip radius, which decreases with lower PMMA concentration.

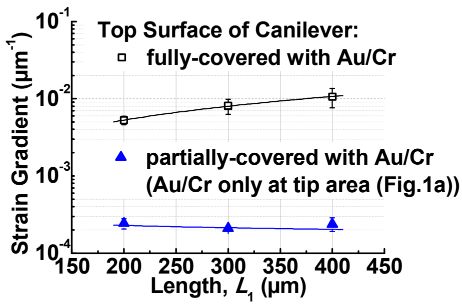

Figure 4: Measured strain gradient as a function of cantilever length, L_1.

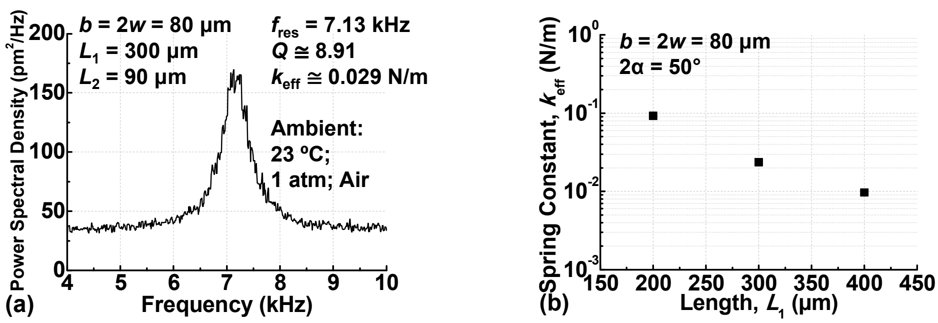

Figure 5: (a) Measured thermal noise frequency spectrum of fabricated cantilevers. (b) Measured k_{eff} values of the cantilevers.