Integrated Optical Glass Microcantilevers for Displacement and Pressure Sensing

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Abstract: A new way to create microcantilevers in glass allows integration of optical waveguides and Bragg gratings. The optical structures are created simultaneously by direct grating writing, followed by high precision dicing and then wet etching to release the glass microcantilevers. Bragg grating interrogation together with piezo-actuation allows the mechanical resonances to be probed, and displacement sensed with an interaction range of 20nm. By varying the pressure of the surrounding air we see a characteristic transition in the mechanical damping from the viscous to the molecular flow regime.

1. Introduction

Microcantilevers are ubiquitous, ultra sensitive sensors used in Atomic Force Microscopy (AFM), pico-molar sensing and as optical antennas. The integrated optical glass microcantilevers utilise Bragg gratings embedded within them to sense mechanical flexure. By combining the Bragg response with the Q-factor of the intrinsic mechanical resonance of the microcantilever, and making use of phase-sensitive detection they are able to create a system that is both decoupled from unwanted background noise and yet is very sensitive to the ambient environment of the cantilever.

2. Optomechanical structure

The novel approach allows us to fabricate our glass microcantilevers without the use of any photolithography and allows us to make cantilevers tens of microns thick which would be prohibitively slow to make using conventional etching. We start with a silica-on-silicon substrate and use direct UV writing [1] to define optical waveguides and Bragg gratings simultaneously, the waveguides and Bragg gratings are literally drawn on to the photosensitive substrate with a UV laser. The microcantilevers are then defined by physical micromachining with a precision dicing saw and released from the silicon substrate by a wet etching process using potassium hydroxide (KOH) to etch away the underlying silicon, as shown in FIG. 1.

a) b)

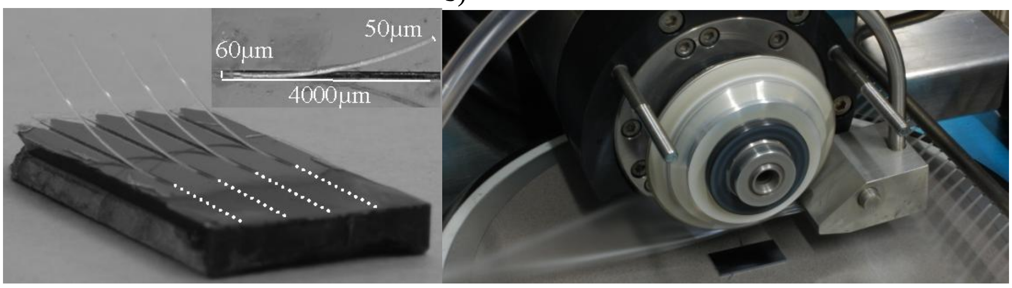

FIG. 1 a) Image of glass microcantilever sensor on the left shows the 5mm by 10mm substrate with 4 glass microcantilevers and the location of the invisible input waveguides. The top insert has the microcantilever dimensions. b) Image of precision dicing saw on right.

3. Experimental results

To investigate how pressure affects the glass microcantilever mechanical resonance response, it was placed in a vacuum chamber. Resonance curves were taken over a pressure range of $1.6\text{x}10^{-2}$mbar to atmosphere. The microcantilever exhibits the characteristic transition from molecular flow to viscous flow at 1 mbar as the pressure is increased and a damped driven oscillator model was used to fit the resonance data. These results agree with the trends reported by Kumazaki *et al.* [2], for the changes in mechanical resonant in a optical fibre cantilever. An additional experiment was preformed to investigate the displacement sensitivity of the sensor. The resulting approach curve shows dampening of the cantilever's mechanical oscillation over a 20nm range, this being comparable to tapping mode AFM.

4. Reference

[1] G. Emmerson, S. Watts, C. Gawith, V. Albanis, M. Ibsen, R. Williams, and P. Smith, "Fabrication of directly UV-written channel waveguides with simultaneously defined integral Bragg gratings," *Electronics Letters*, vol. 38, 2002, p. 1531–1532.

[2] H. Kumazaki, "Pressure dependence of resonance characteristics of the microcantilever fabricated from optical fiber," *Vacuum*, vol. 47, 1996, p. 475-477.