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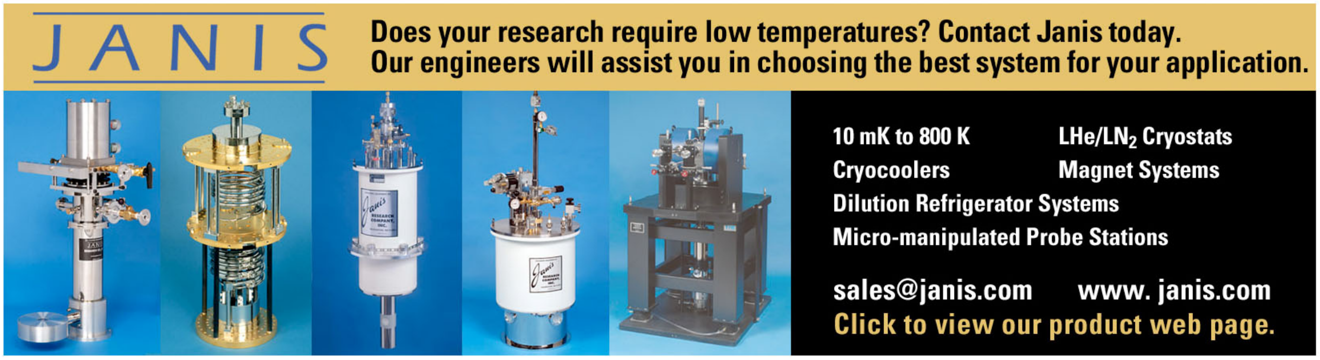

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NOTES

BRIEF contributions in any field of instrumentation or technique within the scope of the journal should be submitted for this section. Contributions should in general not exceed 500 words.

Surface roughness measurement on microchannels by atomic force microscopy using a bent tapered fiber probe

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We demonstrate a high-resolution and nondestructive surface roughness measurement on microchannels by atomic force microscopy with the use of a bent tapered optical fiber probe. The probe was fabricated by a combination of laser heating-pulling and electric arc bending. Microchannels with a width of 41.5 μm and a height of 31.9 μm were fabricated on polycarbonate by excimer laser ablation and the resultant roughness was measured to be 4.8 nm. © *2000 American Institute of Physics.* [S0034-6748(00)00210-0]

The advances in microfabrication technology have realized microfluidic systems for biological diagnosis and chemical analysis.[1–5] To perfect their performance, efforts on quantitative analysis of fluid flow[6–8] inside the microchannels in such systems have also been carried out. In addition to other parameters, the surface roughness is known to play a role and a precise measurement of the roughness is therefore desirable. As the roughness is usually in the nm range, it is difficult to apply conventional techniques such as stylus profilometry, optical profilometry, or scanning electron microscopy for such purposes.

Atomic force microscopy (AFM),[9] on the other hand, is the ideal technique for nanoscale roughness measurement. The tip heights of commercially available AFM probes, however, are in the range of a few microns and thus inadequate for the investigation of microchannels. On the contrary, it is well known that bent tapered optical fiber probes can be produced with controllable bend angles and lengths, and utilized directly in AFM with comparable resolution and without instrument modification.[10,11] In this note, we make use of a bent tapered fiber probe with a bent length of around 750 μm and the desired measurement can thus be realized.

The bent probe was fabricated by a combination of laser heating-pulling[12] and electric arc bending.[11] A commercial CO_2 laser fiber pulser (P-2000, Sutter Instrument) was used to produce a straight fiber probe from a 125 μm telecommunication single mode optical fiber (SMV130, Prime Optical Fiber Corporation, Taiwan). Figure 1(a) shows the end part of a long and thin straight fiber probe with a tip diameter of around 100 nm as determined from scanning electron microscope measurement. The straight probe was then bent by a homemade electric arc instrument. After the bent probe was produced, a 5 nm Pt/Pd film was coated on the back of the probe by ion sputtering (E1010, Hitachi, Japan) to increase the reflectivity necessary for normal force detection. The probe was then glued to a Si substrate for suitable placement in an AFM cantilever holder and the result is shown in Fig. 1(b). The cantilever length, i.e., the length measured from the bent point to the edge of the substrate, and the bent

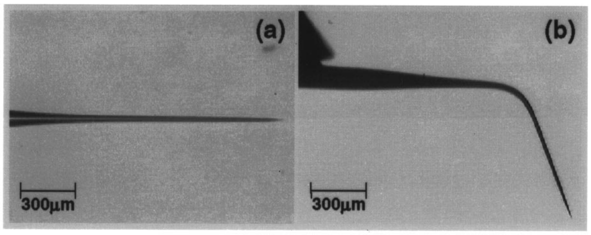

FIG. 1. Photographs of (a) the straight fiber probe and (b) the bent probe with a bend angle of 70°.

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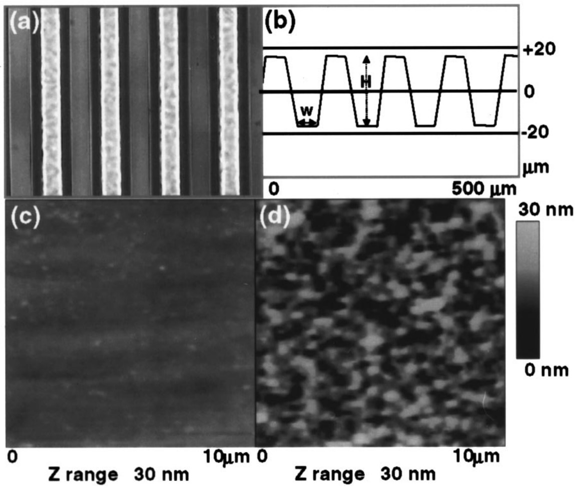

FIG. 2. (a) Photograph of microchannels (bright stripes) on a polycarbonate substrate made by excimer laser micromachining. (b) Surface profile of the microchannels with a width *W* and a depth *H* of 41.5 and 31.9 μm, respectively. (c) 10×10 μm^2 contact mode AFM images on an unexposed region and (d) on a microchannel. The root-mean-square roughness values before and after laser ablation are 0.8 and 4.8 nm, respectively.

length, i.e., the length from the bent point to the tip end, were around 1100 and 750 μm, respectively.

Microchannels were generated on a polycarbonate substrate with the use of an excimer laser micromachining station (Series 7000, Exitech, England) operated at a wavelength of 248 nm. The fabrication detail can be found elsewhere.[13] A photograph of the sample is shown in Fig. 2(a) with the bright stripes corresponding to the irradiated and ablated regions. The channels had a width and a depth of approximately 41.5 (*W* value) and 31.9 μm (*H* value), respectively, as determined by an optical surface profiler (New View 5000, Zygo, USA) and the result is shown in Fig. 2(b).

Tapping mode AFM was first tested on the sample, but the resolution was not high enough if a large probe vibration amplitude was set as the feedback. For a small feedback amplitude, the sample surface was unfortunately easily damaged. On the contrary, high-resolution images could be obtained without sample damage by using a small force in contact mode operation. Surface images of 10×10 μm^2 at an unirradiated region and a microchannel are presented in Figs. 2(c) and 2(d), respectively. The root-mean-square roughness values before and after laser exposure are approximately 0.8 and 4.8 nm, respectively. Also Fig. 2(d) provides a detailed picture of surface roughening. Application of the present technique could potentially make a valuable contribution to a precise understanding and control of the fluid flow in microfluidic systems.

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