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Microfluidic Device with Accurately Aligned Optical Fibers for Measuring Transmission Spectrum Using Supercontinuum Light

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Abstract

The microfluidic device for measuring the transmission spectrum using the supercontinuum light across the liquid channel is developed. For the accurate alignment of the optical fibers, the bias spring with the reversely tapered profile is newly introduced realizing the high transmission ratio. Infra-red absorption spectrum is measured for obtaining the molecular information. When the water is introduced in the channel as the demonstration, the characteristic absorption peak is clearly confirmed.

1. Introduction

Supercontinuum (SC) light is attractive for many fields. Its spectrum expands from ultraviolet to infrared (up to 6.28μm) using a cm-long fluoride fiber as the non-linear material [1]. MEMS devices have been combined with the fiber in the telecom applications. From mid-IR, the molecular vibration spectrum can be measured. Many molecules are IR active and have their own absorption peaks. Figure 1 shows the concept of the microfluidic device in this study. The micro-channel for flowing liquid and particles can be well combined for analyzing materials in liquid. The device reported last year suffers from the low optical transmission ratio [2].

In this study, a new alignment bias spring for the accurate fiber setting is introduced.

2. Design

Figure 2(a) shows the whole device design with the crossing point between the light path (vertical) and the liquid channel (lateral). The ends of the optical fibers are placed face to face. For increasing the transmission rate, the gap between the fiber ends is decreased from the previous design of 104 to 35 μm. This gap becomes the liquid channel. 1.3mm-wide trenches of the liquid channel at left and right sides is for making the setup easy for connecting the syringe. Figure 2(b) shows the magnified design around the crossing point. GI fiber with 50 μm-diameter core is combined.

The mechanical alignment accuracy (position and angle) becomes important for getting the high coupling ratio between fibers. Figure 3 shows the schematic drawing of the bias springs pushing the fiber to the reference planes at the left sides. The conventional vertical spring (A-A') only works laterally. The reversely tapered profile (B-B') is for setting the fiber not only laterally but also vertically with the corner.

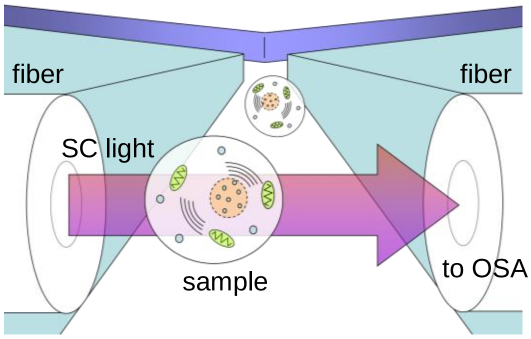

Fig. 1 Concept of microfluidic device for measuring transmission spectrum.

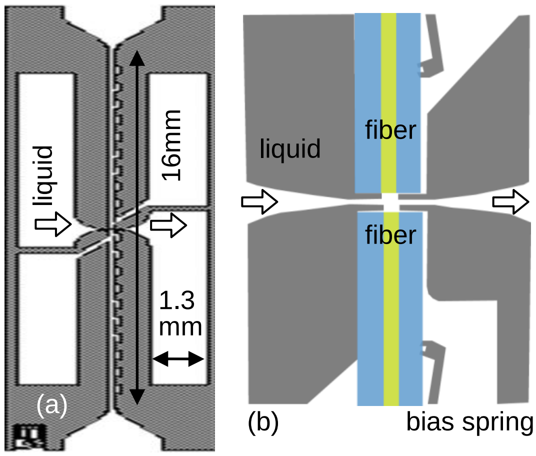

Fig. 2 The whole view of the device and magnified intersection between the optical axis and the liquid channel.

3. Fabrication

Figure 4 shows the fabrication sequence. SOI device Si layer is 125 μm thick. The top surface has 1 μm-thick SiO_2 film and the first mask pattern is transferred (step 1). The second mask is for giving the reversely tapered profile (step 2). The subsequent etching gives the vertical profile first and then the over-etched one (step 3). The balance of the etching (14s) and the deposition (8s) in one cycle of the deep RIE is shifted to the over-etching by increasing the time to 16s. After the resist mask is removed, the vertical etching is carried out for making the other sidewall of trench and bais springs using the SiO_2 mask (step 4). The recipe of SOI notch protection avoids the notching problem.

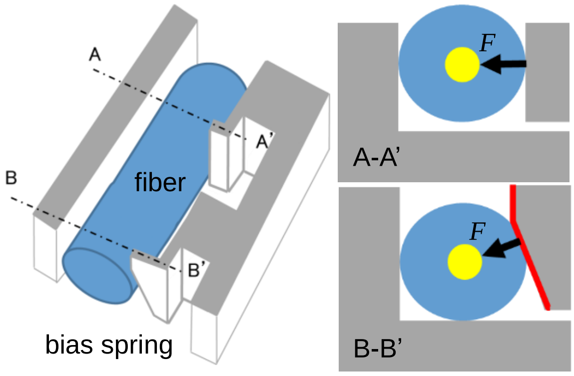

Fig. 3 Schematic drawing of bias spring with (A-A') vertical and (B-B') reversely tapered profile.

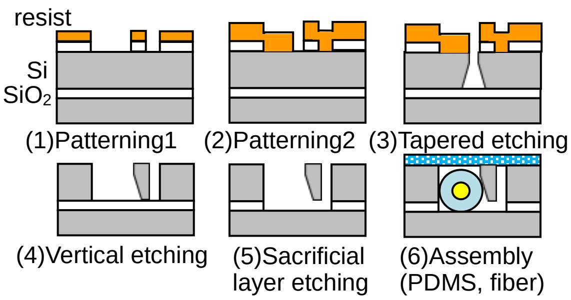

Fig. 4 Fabrication sequence.

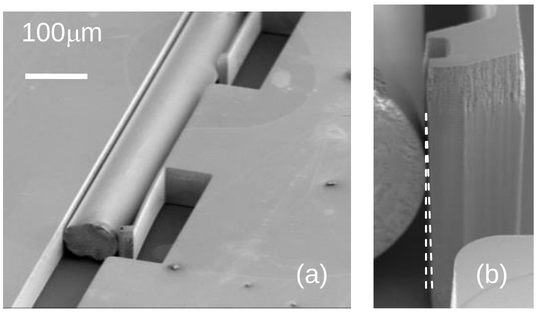

Fig. 5 Fabricated device and optical fiber. The with and the length of the bias spring is 10 and 270 μm, respectively.

The sacrificial SiO_2 etching releases the bias spring (step 5). The cantilever is released by drying from the liquid fluorinert (3M, C_mF_n, m,n=1,2,3…) having low surface tension. The top cover of PDMS film (Toray Silpot 184) is passed after the hole-opening for the syringe connection. The fiber having 125μm-diameter is set in the trench (step 6).

Figure 5(a) shows the bias spring and the fiber. The fiber is manually inserted and fixed without the special tool. The inverse taper is 1-2degree as can be seen in Fig. 5(b). The contact point between the bias spring and the optical fiber is 68μm from the base plane, which is larger than the fiber radius. The bias spring pushes the fiber downward.

4. Results

Figure 6 shows the optical signals. Red curve is obtained when the visible light source is directly connected to the optical spectrum analyzer (OSA). Black and blue curves are obtained from the device with the bias springs with the reversely tapered and the vertical profile (fabricated as the reference), respectively. The reversely tapered profile improves the optical transmission rate by about 2-times.

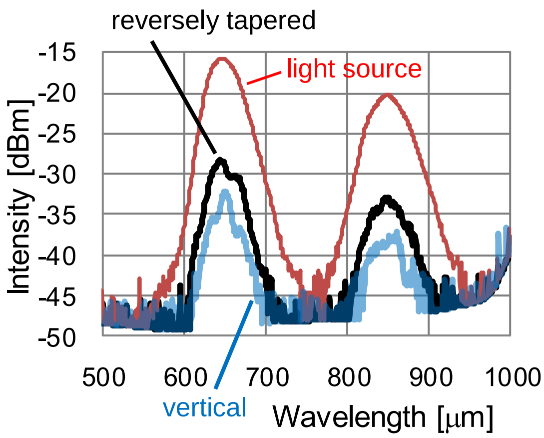

Fig. 6 Transmitted optical signals aligned by bias springs.

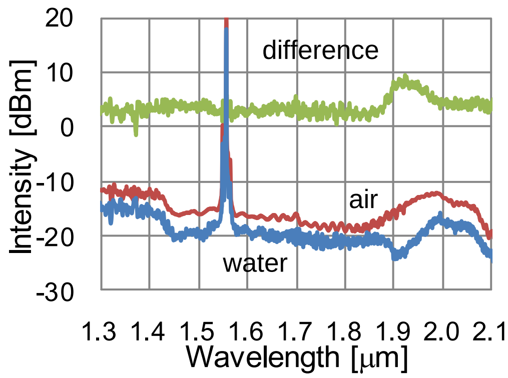

Fig. 7 Transmission spectra obtained through air and water. The peak at 1.55μm is the excitation light for generating SC light.

Figure 7 shows the transmission spectrum obtained using the fabricated device and SC light source (SC450, Fianium). The red and blue curves are the spectra obtained through air and water, respectively. When the water is introduced, the light intensity decreases over the wavelength (This does not occur for the visible light). The green curve is the difference showing the absorption spectrum. The intensity of the differential spectrum increases about 50 times compared to one obtained last year. The absorption peak is at the wavelength of 1.95μm. According to HITRAN data base of the water molecule, the absorption bands are at the wavelength of 1.87μm. The red-shift phenomenon is explained by the hydrogen bonding between water molecules in water liquid compared to the gas.

Acknowledgements

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References

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