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Fabrication and characterization of an egg-shaped hollow fiber microbubble

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ABSTRACT

In this paper, an egg-shaped microbubble is proposed and analyzed firstly, which is fabricated by the pressure-assisted arc discharge technique. By tailoring the arc parameters and the position of glass tube during the fabrication process, the thinnest wall of the fabricated microbubble could reach to the level of 873nm. Then, the fiber Fabry–Perot interference technique is used to analyze the deformation of microbubble that under different filling pressures. It is found that the endface of micro-bubble occurs compression when the inner pressure increasing from 4Kpa to 1400KPa. And the pressure sensitivity of such egg-shaped microbubble sample is14.3pm/Kpa. Results of this study could be good reference for developing new pressure sensors, etc.

Keywords: Fabry-Perot interference, Pressure-assisted arc discharge, Microbubble

1. INTRODUCTION

Microbubble structures on optical fiber could be very useful for promoting the development of new optical fiber technology [1]. At present, various techniques could be used to fabricate such microbubble structures[2,3,4]. In upper methods, the splicing machine or CO_2 laser based fabrication methods are more flexible in building the microbubble due to the accurate adjusting capability of heating time, discharge intensity and fiber location. But these methods need improvement on optimizing the thickness, the concentricity and the asymmetry of microbubble structures. The hydrofluoric acid etching method was used to reduce the thickness of micro bubble. But the drawback of such method is that it would increase the transmission loss and reduce the quality factor in whispering gallery mode applications [5].

In this paper, a new method is proposed to fabricate the ultra-thin hollow fiber microbubble structure. This method is based on the pressure-assisted arc discharge technique, which possess the merit of using weak discharge and releasing pressure gradually during the arc discharge process. The wall thickness of the fabricated micro-bubble would be as low

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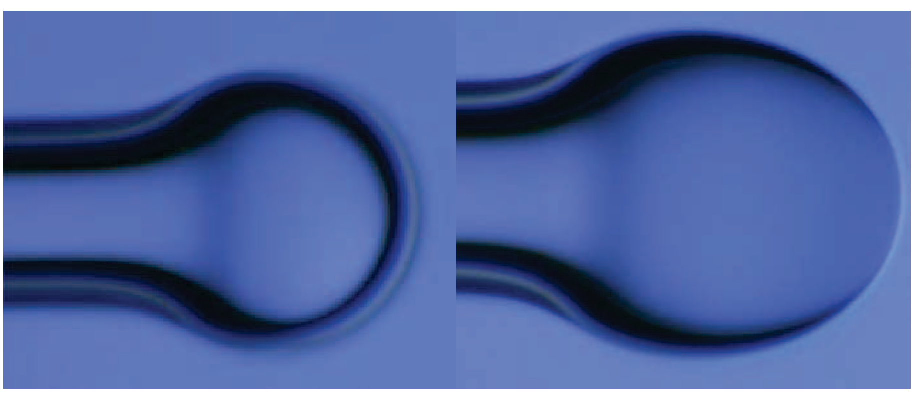
as ~1 micron. Besides, the pressure sensitivity of the bubble is also analyzed by using Fabry-Perot (FP) interference method. The pressure sensitivity of such egg-shaped microbubble sample is14.3pm/Kpa.

1.1 Microbubble fabrication

The microbubble was fabricated by using pressure-assisted discharge technology. The silica glass tube that utilized for fabricating microbubble has the outer/inner diameter of 125μm/75μm respectively. While the plastic coating of the tube was removed before the fabrication experiment. An optical fiber fusion machine (type: Fujikura 60s) was used to discharge the electric arc. And a pressure pump (type: Kangsite Instrument ConST162) was used to provide the high pressure to the glass tube.

Firstly, the glass tube is fused with a common single-mode fiber. Secondly, an atmosphere pressure of 120KPa is filled into the glass tube, and the glass tube is moved towards to the electrode region. Then, a certain force is imposed at the dual-end of glass tube by moving the motor toward to the outer direction, and arc discharge again. After about three times of discharge, the glass tube is split into two fractions, and two hollow cone structures appeared. Thirdly, this hollow cone is placed vertically between the two electrodes. While the end of the hollow cone has some distance with the center of the two electrodes. Thus, the hollow cone is discharged several times under the condition of filling the glass tube with air pressure P, while the hollow cone is rotated during the pitch of different discharges. Finally, a microbubble with circular structure and thick wall is shaped(Fig.1a). Such rotation method could help to improve the uniformity of bubble thickness. Here the arc intensity and discharge time is -5Bit and 300ms. The filled pressure is about 120KPa. Fourthly, the end surface of microbubble is moved closer to the electrode, and then discharged again. In this way, the expansion effect of the end surface of microbubble is obvious, which makes the end surface is very thin after discharge(Fig.1b).



(a) (b)

Fig.1 micro-bubble process pictures(a)Preliminary structure of micro-bubble (b) egg-shaped microbubble

1.2 FP interference experiment and analysis

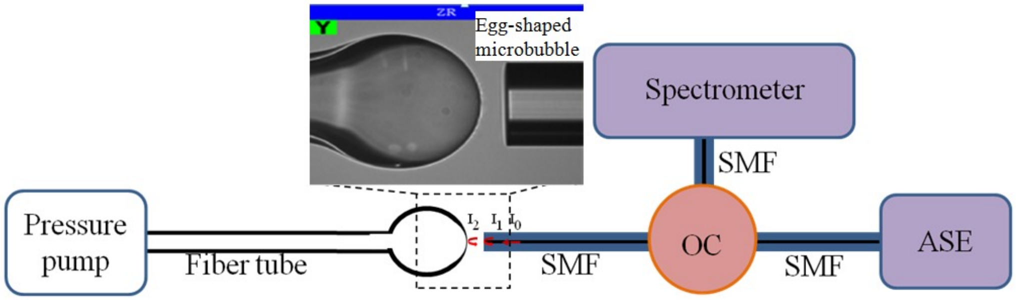
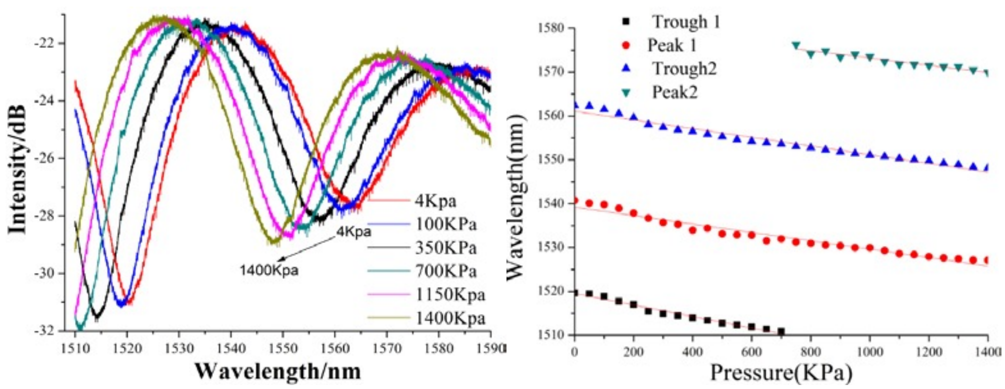


Fig.2 Method to test the pressure sensitivity of micro-bubble using fiber FP interference

In this section, an experimental system as shown in fig.2 is set up to analyzing the mechanical properties of such egg-shaped microbubble. It consists of a glass tube that connected to the pressure pump, fiber circular, ASE laser source, spectral demodulator and a singlemode fiber. The end of the singlemode fiber is closed to the outer end of the microbble, thus a FP interference phenomenon is occurred between the end of fiber and microbubble. The distance d between the end of the microbubble and the single-mode fiber can be calculated from the FP interference spectrum.

Fig. 3a shows the shift of the FP interference spectrum under different pressures. It can be seen that with the increase of filling pressure, there is red shift. When the filling pressure is 4KPa, the peak wavelength of the interference spectrum is around 1540nm and 1585nm. While when the filling pressure is at 1400KPa, the interference peak is near 1525nm and 1570nm. Fig.3b shows the relationship of the interference peaks and the filling pressure. It seems that the spectral peak deformation sensitivity vs. the filling pressure is about 14.3pm/KPa.



(a) (b)

Fig.3 Results of FP interference experiment (a) Spectrum of FP interference experiment. (b)Relationship between deformation of micro-bubble and filling pressure

Compared with the conventional fiber-optic FP pressure sensor of thin-film structure, the fabricated microbubble in this paper has two advantages. One is that the wall thickness of the microbubble is very thin and the surface area is large. While the other thicker parts play the role of arm. The second is that the detected pressure is filled into the inner area of the microbubble but not outside, thus the outward microbubble expansion will occur. Here the membrane molecular tension plays a significant role, so it is easy to suffer a large deformation. To the contrary, many microbubble structures in previous reports are used to detect the outer external air pressure. It is not optimistic to attain a large deformation due to the external extrusion pressure, which restrict their sensitivity potential. Thus, the microbubble structure reported in this paper is more prone to deformation and attaining higher detection sensitivity under the similar bubble parameters.

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