Extended Abstracts of the 2002 International Conference on Solid State Devices and Materials, Nagoya, 2002, pp. 836–837

LF-1-3

MEMS device for controlling evanescent field on side polished optical fiber

JongHyeong Song, Yohei Taguchi, Minoru Sasaki, Kazuhiro Hane

Department of Mechatronics and Precision Engineering, Tohoku University,
Aramaki 01, Aoba-ku, Sendai 980-8579, Japan
Phone: +81-22-217-6965 Fax: +81-22-217-6963 E-mail: song@hane.mech.tohoku.ac.jp

1. Introduction

Optical MEMS has gathered significant attention especially in the field of the fiber-optic communication. The micro-mechanism for controlling the propagating light directly without conversion to the electrical signal matches with the technical trend for the all-optical network, which will improve the system reliability. The optical switches or cross-connects are researched in many companies up to now. The variable optical attenuator or the tunable filter is also researched. The device scheme intrinsically combined with the optical fiber is one ideal, since it can be easily inserted in the communication network. The combination of the moving MEMS element and the side surface of waveguide has been proposed by the Fujita group of the University of Tokyo in 1998.[1] The combination with the side-polished optical fiber is tried by the Cornell University group in 2000.[2] The interaction via the evanescent field is expected to realize the large change in the optical property even if the moving displacement of the MEMS element is small. In this study, two different MEMS devices combined with the side polished optical fiber are described.

2. Experiments and Results

Hybrid type moving diaphragm fabrication

The combination of the moving diaphragm and the optical fiber is realized by preparing MEMS device and side polished fiber separately. The moving diaphragm is fabricated using a usual surface micromachining technique. The structural layer is the LPCVD grown doped poly-Si and the sacrificial layer is the TEOS SiO_2. Figure 1 shows the schematic diagram and fabricated device of hybrid type moving diaphragm for interacting with the side polished optical fiber. The moving diaphragm is in the anisotropically etched cavity. The height of the moving diaphragm is adjusted to be a little higher (~0.5 µm) than the cavity depth for interacting with the side polished fiber. The surface roughness poly-Si diaphragm is 20 nm in average. Side polishing of the fiber near to core was accomplished by using a usual polishing machine. The optical fiber is fixed on the base plate being curved smoothly for interacting with the diaphragm. And polishing depth was examined by liquid drop test.[3] The relative alignment between the fibers is carried out under the view of optical microscope. The alignment mark is prepared on the glass holder on which the MEMS device is fixed.

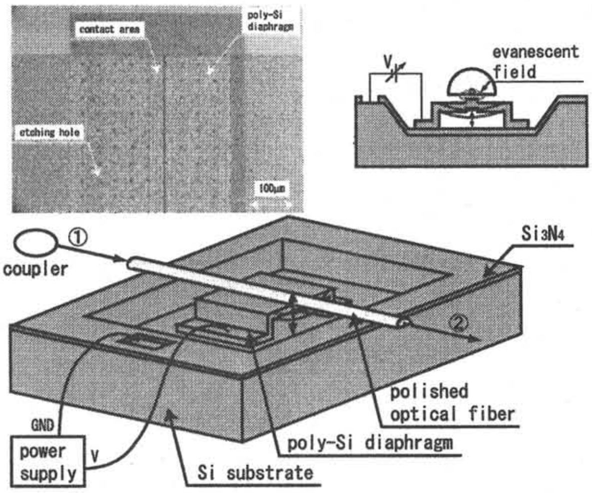

Figure 1. Schematic diagram and fabricated diaphragm of hybrid type moving diaphragm for attenuator.

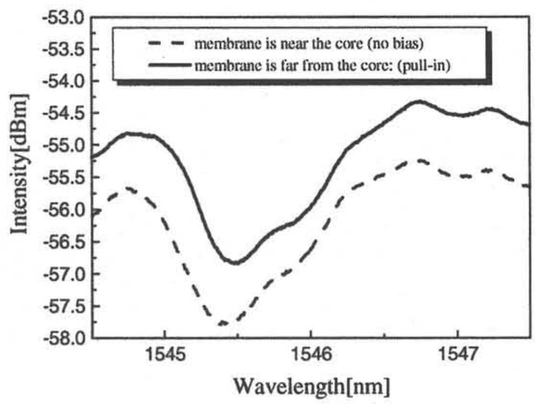

Figure 2. Transmission spectra of side polished fiber depending on the membrane position

Figure 2 shows the transmission spectra when the driving voltage is applied and not applied. Depending on the membrane position, the transmitted power changed. When the membrane is attached on the side polished fiber, the transmitted power decreases by about 1 dB compared with that at the detached status. This result indicates that the fabricated diaphragm reacts with the evanescent field generated on the side polished optical fiber. The interaction may occur only at some point not whole area. This is because the interaction whole area should change the Bragg wavelength position. The depression peak at ~1545.5 nm is originally the Bragg grating spectrum peak at about -8 dB. The optical spectrum becomes shallow and the transmission rate becomes low showing the leaky property. This result indicates that the polishing reaches to the core and the polishing depth is enough to interact with the diaphragm. For the whole area contact, parallel alignment between the fiber and the diaphragm is critical.

Fabrication of monolithic type diaphragm

The previous hybrid type attenuator requires the accurate position and gap control between the side polished optical fiber and the MEMS diaphragm. For solving this assembly difficulty, the monolithic type device is developed. Figure 3 shows schematic drawing and fabricated result of the monolithic type device. The optical setup is pre-aligned during the process. There is another advantage. The electrode is placed on the polished optical fiber therefore the large attractive force approaches the diaphragm to side polished fiber surface. This makes stable interaction between the diaphragm and the fiber can be obtained. This is contrastive to the previous hybrid type moving diaphragm, where the contact is relied on the initial mechanical alignment. At the center of the diaphragm, the bushing is prepared for ensuring the local contact along the fiber core.

The short length (~17 mm) of optical fiber is fixed on the Si V-grooves using poly-imide as the glue material, optical fiber is polished near to the core, and moving diaphragm is prepared by the post-process. The structural layer is the PECVD grown SiN and thermally deposited Cr, and the sacrificial layer is the PECVD grown a-Si. The structure layer is released by etching a a-Si using XeF_2 gas. The process can match with batch fabrication. The optical alignment for transmission measurement can be carried out by inserting two optical fibers along V-grooves without special tools.

Figure 4 shows the transmission spectrum when the moving diaphragm is at the detached or the attached positions. The spectrum is measured at the position where the transmission becomes maximum power. The transmission power decreases by 0.5 dB at ~1450 μm when at the attached condition. The wavelength dependence of the spectrum is natural considering the coupled-mode theory. Small transmission intensity change in the fabricated device is caused by insufficient fiber polishing. For the single mode fiber, the fine control of the polishing depth is necessary.

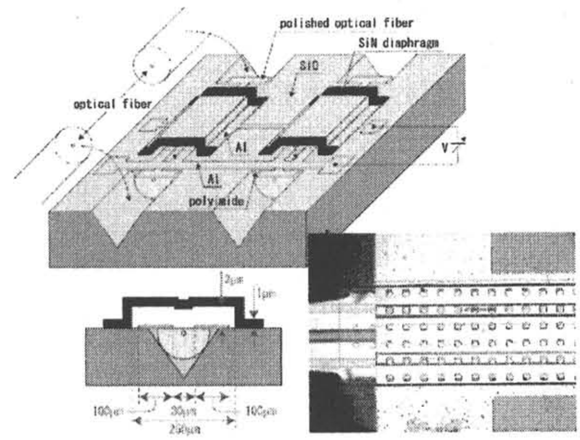

Figure 3. Schematic drawing and fabricated diaphragm of monolithic type MEMS device for attenuator.

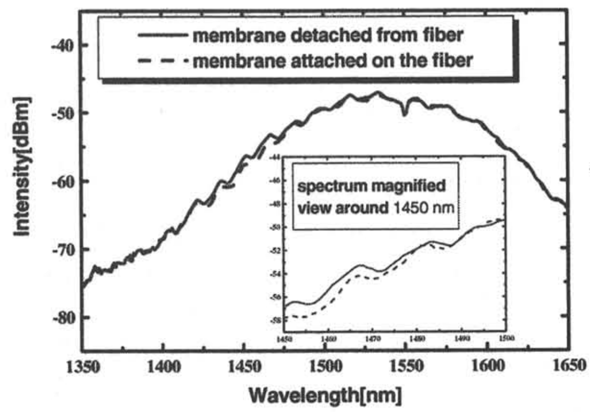

Figure 4. Transmission spectrum of monolithic type device.

3. Conclusions

Two different electrostatic driving type MEMS devices are developed for realizing the interaction via evanescent field of the narrow gap. The change in the transmission spectrum is minute than the expected value. This implies the difficulty of perfect surface to surface interaction via the air gap. Fine control of polishing depth and parallel alignment of side polished fiber with diaphragm are the critical factor for sufficient interaction of diaphragm with evanescent field.

References

[1] F.Chollet, M.de Labachelerie, H.Fujita, *Proceedings of MEMS*, 476 (1998)

[2] Junting Liu, Jay Y. Jeong, Minfan Pai, Cliffor R. Pollick, Norman C. Tien, Dieter C. Ast, *Proceedings of Int. Conf. Optical MEMS*, 109 (2000)

[3] Andrey Tz. Andreev, Blagovesta S. Zafirova, Elka I. Karakoleva, *Sensors and Actuators* **A64**, 209 (1998)

Acknowledgments

Part of this work was performed at the Venture Business Laboratory in Tohoku University.