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Semiconductor MMI Optical Isolator with Cladding of Ce:YIG

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1. Introduction

For optical communication systems, the importance of the optical isolators has been greatly increased to protect the devices from a light coming backward. However, the currently existing optical isolators are bulky and cannot be integrated with other devices. Thus, the optical isolators integrated with the optical devices are strongly required. Recently, novel devices using magneto-optic effects as the isolators and circulators have been proposed [1, 2]. To realize them, the nonreciprocal phase shift depending on the propagation direction of the light has been used.
In this paper, the semiconductor MMI optical isolator with the CE:YIG is fabricated. Also, isolation ratio is measured by using the nonreciprocal phase shift, which is caused by applying magnetic field through the device.

2. Device structures and Fabrication Processes

As shown in Fig. 1, the length of the device, the width and the length of MMI structure are 30 μm and 1956.8 μm, respectively. The device structure is consisted of InGaAsP core and InP substrate. The width of waveguide is 4 μm, and the thickness of core layer is 450 nm. To support the adherence of Ce:YIG and distribute the power imposed on MMI, a Ce:YIG supporting layer has been used.

The upper cladding layer of the Ce:YIG was contacted with the MMI with the InGaAsP core layer of the MMI [3]. Before bonding the wafer with the Ce:YIG garnet, both the MMI and the Ce:YIG are cleaned in following order: TCE, acetone, and methanol. The MMI and the Ce:YIG are placed in an O_2 plasma asher for 1 minute under the conditions of 0.3 Torr and 100 W RF power. To form the hydrophilic surfaces, the MMI and the Ce:YIG are dipped into the solution of $NH_4OH:H_2O:H_2O_2$ = 5ml:150ml:20ml for 5 minutes. The MMI and the Ce:YIG are cleaned in methanol, and then, bonded directly in methanol. The bonded sample is placed in a graphite sample holder for strengthen the bonding of the MMI and Ce:YIG.. The graphite sample holder is placed in the furnace for 90 minutes under the temperature of 220°. With these complete bonding processes, the successful bonding of the MMI and the Ce:YIG, now called a MMI isolator, is obtained. These processes are well depicted in Fig. 2.

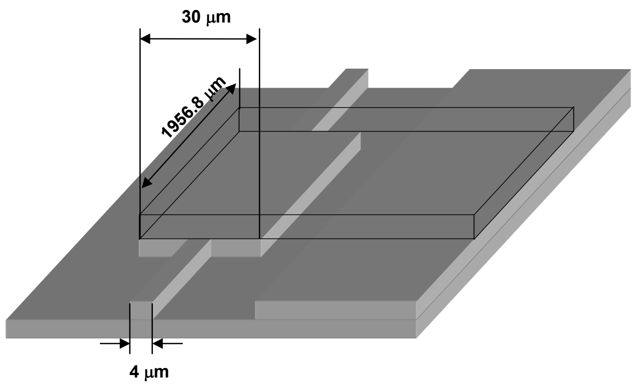

Fig. 1. Structure of semiconductor MMI optical isolator with Ce;YIG.

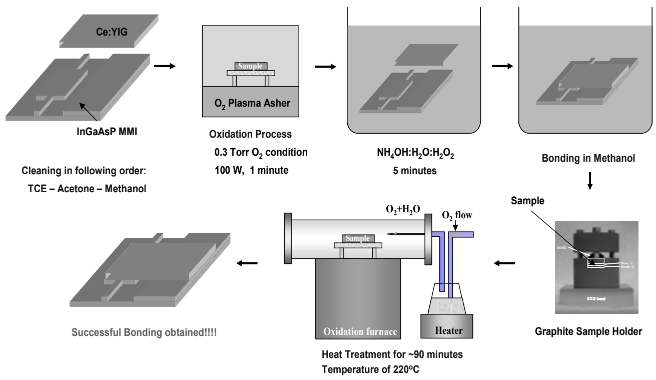

Fig. 2. Bonding processes between InGaAsP and Ce:YIG

3. Measurement Results of Isolation Rate

Using a magnet, external magnetic field is applied to the MMI isolator. The input optical wave propagating through the MMI isolator is influenced by the phase shift due to the external magnetic field. This effect also influences the output intensity. In forward direction, the MMI isolator has been designed to yield the maximum intensity under the influence of the external magnetic field to generate Faraday rotation. However, in backward direction, the nonreciprocal phase shift occurs in MMI. With this effect, the focal point of the MMI is not located at the waveguide. In other words, the optical light traveling through the MMI is diffused into other locations, not focused into the waveguide. Therefore, the output in the backward direction has relatively smaller intensity than that of forward direction.

To measure the isolation rate of the fabricated devices, the TM mode optical wave with the wavelength of 1.55 μm is propagated through the device. To cause the different phase shift for forward and backward directions, the magnetic field with different polarity is applied for the forward and backward directions. The same measurement method described in [4] is used. Figure 3 shows the intensities of the outputs in forward and backward directions. In the forward direction, the intensity of -37.8 dBm is obtained. In the backward direction, the intensity of -40.7 dBm is obtained. The optical intensity of the optical wave propagating in backward direction is 2.9 dB smaller than that of forward direction. Therefore, the MMI isolator with the isolation ratio of 2.9 dB is successfully demonstrated.

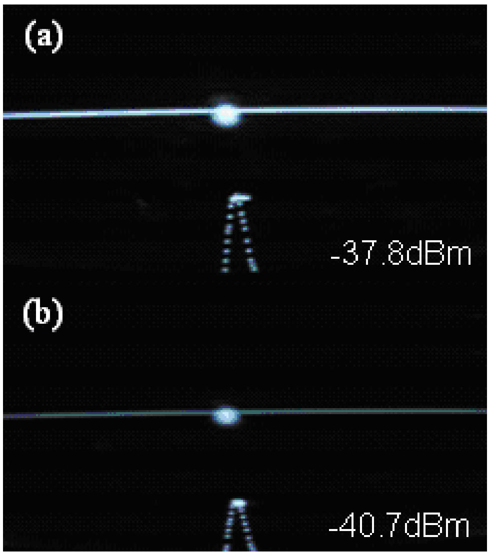

Fig. 3. Near field pattern and optical intensity of output in TM mode, (a) forward direction, (b) backward direction.

4. Conclusion and discussion

The MMI structured semiconductor optical isolator whose cladding layer is the Ce:YIG is demonstrated. The isolation ratio of 2.9 dB is obtained. The main advantage of this device is that the length of the devices is relatively short compared to other isolation-purpose devices. However, this short device length also gives disadvantage that the short length of the MMI region can cause small Faraday rotation.

The relatively small isolation ratio is obtained because of imperfect direct bonding and not fully optimized MMI structure design. Also, the short length of the MMI region may be the other factor limiting the efficiency of isolation. Further improvements in direct bonding condition and MMI structure design will greatly increase the isolation ratio.

References

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