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Fabrication of Dual-disks Microlasers in Thiophene/Phenylene Co-oligomers

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1. Introduction

Thiophene/phenylene co-oligomers (TPCO) are attracting much attention for photonic devices[1-13]. The TPCO crystals show the good performance of field effect transistors[3,4] and electroluminescence[5,6] and show the high photo-excited emission yields even at room temperature. Crystals and films of TPCO also exhibit amplified spontaneous emission (ASE) and laser oscillation under a high intensity optical excitation at room temperature[7-10]. Both the good performance of electronic and photonic properties in TPCO crystals are useful for the current injected lasing on organic semiconductors.

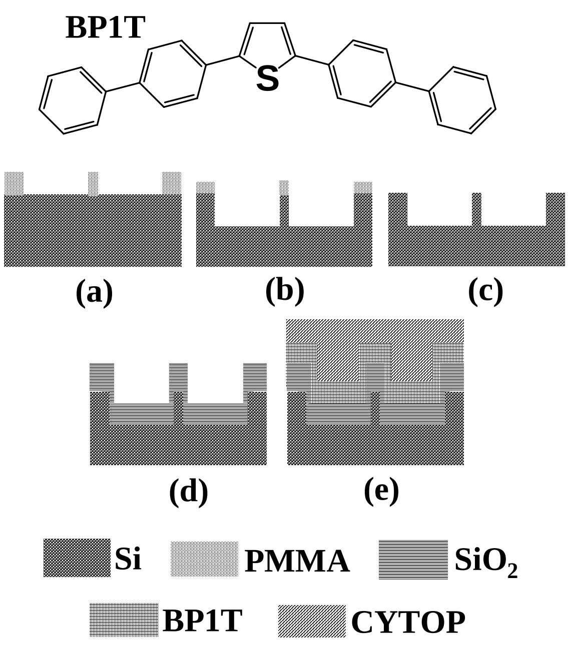

Fig. 1 The upper part shows molecular structure of the BP1T co-oligomer. The lower part shows schematic drawing of fabrication processes of microcavities; (a) EB lithography, (b) SF_6-RIE of Si substrates, (c) O_2-RIE of the remained PMMA film, (d) SiO_2 sputtering, and (e) thermal deposition of BP1T films and overcoating of cytop films.

Further, recent reports indicate there are a wide variety of optical amplification processes in TPCO systems, such as the stimulated resonance Raman scattering and delayed optical amplification[11-13]. The stimulated resonance Raman scattering and delayed optical amplification are useful for the wavelength conversion and photonic buffer memory, respectively. We have fabricated micro resonator of TPCO films on Si/SiO_2 substrates and showed the laser emission with the whispering gallery modes. Here, we report the results of fabrication method of dual-disks microcavities and their laser emission properties.

2. Experiments

Figure 1 shows the flow diagram of the fabrication processes. At first, we used electron beam (EB) lithography to make patterns of microdisks on the resist. Microdisk patterns were formed on Si substrates by means of reactive ion etching (RIE) with the SF_6 gas. Remained PMMA resist was removed by the RIE with O_2 gas and ultrasonic cleaning in acetone. One of the TPCO, 2,5-bis(4-biphenylyl)thiophene (BP1T) co-oligomer[1,2] films were formed on Si substrates by means of thermal vapor deposition with 200nm thickness. The overcoat layer of amorphous fluorocarbon polymer, Cytop CTX804.5A (ASAHI GLASS Co. LTD. Japan) was spin-coated on a BP1T film with 300nm thickness. The overcoat layer acts as preventing the evaporation of BP1T molecules during the annealing. The films were annealed on a hot plate and crystallized at 220 °C.

The microscope images of dual-disks are shown in Fig. 2. Two microdisks were fabricated with the spacing of 500, 350, and 0 nm, as shown in Fig. 2. Here, we call these dual-disks (DD) as DD500, DD350 and DD0, respectively.

We carried out experiments of pulse excitation at 397 nm with a 10-15 ps width onto the dual-disks. The spot size was about 100 μm in a diameter. All experiments were carried out at room temperature. Figure 3 shows the laser emission spectra of DD350. The excitation density was 400-600 $\mu J cm^{-2}$. Lasing peaks observed around 2.68-2.70 eV are the 0-1 vibration lines[14]. The lasing spectra show nearly regular intervals, indicating the whispering gallery modes (WGM) in microdisks. Both the spectra were obtained in the different DD350 cavities. If both DD350 cavities have precisely same structures such as in diameter and cracks so on, the lasing spectra should be the same. However, the lasing spectra show different mode width and intervals each other. The lasing spectra observed on the different spacing cavities were much varieties. The facts indicate the poly crystalline boundaries and cracks in the cavities affect lasing spectra so much. On the other hand, decrease of the lasing threshold observed in the dual-disks cavities are reduced to 1/3 to 1/4 of that in the bulk film part. This reduction of lasing threshold is rather constant in almost all cavities.

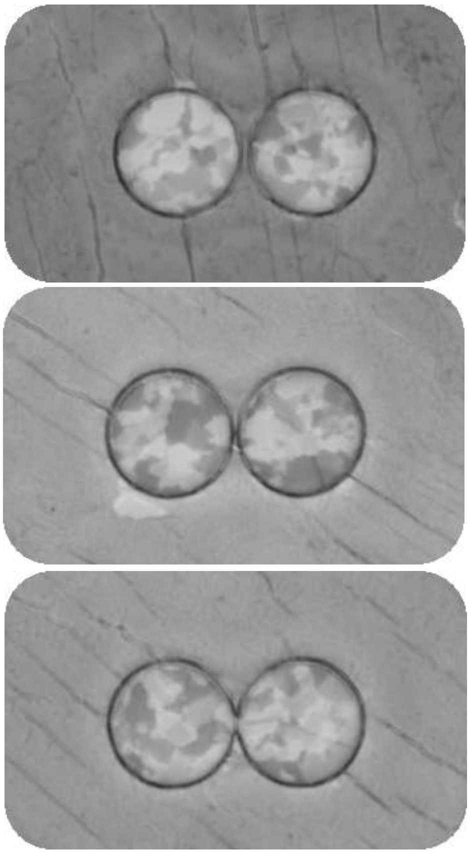

Fig. 2 Microscope images of dual-disks with the spacing of 500(upper), 350(middle), 0(bottom) nm, respectively. Diameters of all disks are 9 μm.

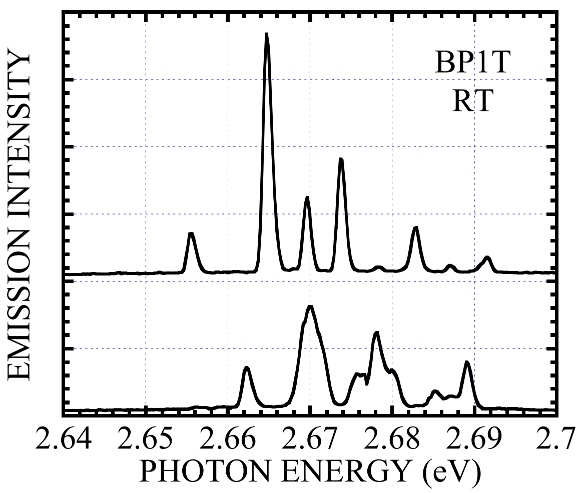

Fig. 3 Lasing spectra of DD350.

3. Conclusions

We have succeeded fabrication of dual-disks microlasers. The lasing spectrum of the dual-disks cavity strongly depend on the cavity structure, but the reduction of lasing threshold is rather constant value in almost all of dual-disks cavities.

References

[1] S. Hotta, H. Kimura, S. A. Lee, and T. Tamaki: J. Heterocyclic Chem. **37**(2000)281.

[2] S. Hotta and M. Goto: Adv. Mater. **14**(2002) 498.

[3] M. Ichikawa, H. Yanagi,Y. Shimizu, S. Hotta, N. Suhanuma, T. Koyama and Y. Taniguchi: Adv. Mater. **14** (2002)1272.

[4] K. Nakamura, M. Ichikawa, R. Fushiki, T. Kamikawa, M. Inoue, T. Koyama and Y. Taniguchi, Jpn. J. Appl. Phys. **44**, L1367(2005).

[5] H. Yanagi, T. Morikawa and S. Hotta: Appl. Phys. Lett. **81**, 1512(2002).

[6] M. Ichikawa, K. Nakamura, M. Inoue, H. Mishima, T. Haritani, R. Hibino, T. Koyama and Y. Taniguchi, Appl. Phys. Lett. **87**, 221113(2005).

[7] R. Hibino, M. Nagawa, S. Hotta, M. Ichikawa, T. Koyama and Y. Taniguchi: Adv. Mater. **14**, 119(2002).

[8] M. Nagawa, R. Hibino, S. Hotta, H. Yanagi, M. Ichikawa, T. Koyama and Y. Taniguchi: Appl. Phys. Lett. **80**, (2002)544.

[9] M. Ichikawa, R. Hibino, M. Inoue, T. Haritani, S. Hotta, K. Araki, T. Koyama, and Y. Taniguchi, Adv. Mater. **17**, 2073 (2005).

[10] K. Shimizu, Y. Mori, and S. Hotta, J. Appl. Phys. **99**, 063505 (2006).

[11] H. Yanagi, A. Yoshiki, S. Hotta and S. Kobayashi: Appl. Phys. Lett. **83**, (2003)1941.

[12] H. Yanagi, A. Yoshiki, S. Hotta and S. Kobayashi: J. Appl. Phys. **96**, (2004)4240.

[13] F. Sasaki, S. Kobayashi, S. Haraichi, H. Yanagi, S. Hotta, M. Ichikawa and Y. Taniguchi, Jpn. J. Appl. Phys. **45**(2006)L1206.

[14] K. Bando, T. Nakamura, Y. Masumoto, F. Sasaki, S. Kobayashi and S. Hotta: J. Appl. Phys. **99**, (2006)013518.