3D μ-printed polymer whispering-gallery-mode microcavity laser sensor array

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Development of low-cost, portable and sensitive microdevices for identification of various sample are demanding in various practical applications [1]. To fulfil the demand of multi-parameter sensing, on-chip whispering-gallery-mode (WGM) microcavity sensor array has attracted lots of research interest [2]. However, it remains a challenge to rapidly fabricate arrays of polymer WGM microcavities and integrate with functional materials for sensing applications. Here, we demonstrate the fabrication of WGM laser array by using an optical μ-printing technology [3,4]. The technology enables rapid printing of polymer mushroom-like WGM microcavities and integration with a gain layer and a humidity sensing layer for relative humidity (RH) sensing.

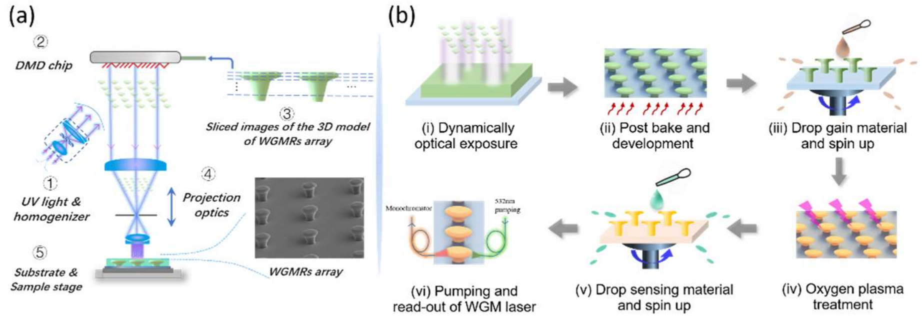

Fig. 1 (a) Schematic of the optical μ-printing technology. (b) Processing flow for WGM microcavity laser array.

Figure 1(a) shows the schematic of optical μ-printing technology. A homogenized UV light beam illuminates the digital mirror device (DMD) chip which loads the sliced images of the 3D model of WGM microresonator array and generates corresponding optical patterns. The optical patterns are projected on the prepared photoresist by a scale-down projection optics. The exposed photoresist was post baked and developed to achieve 3D WGM structures, as shown in Fig. 1(b). Rh6G doped SU-8 was then spin-coated upon the 3D structures to enable optically pumped lasing operation. Thereafter, the samples were treated by plasmon and then spin-coated with a PVA layer for humidity sensing. The microcavities were pumped by a 532-nm pulse laser, and the light is delivered via and collected by two in-plane multimode optical fibers, respectively.

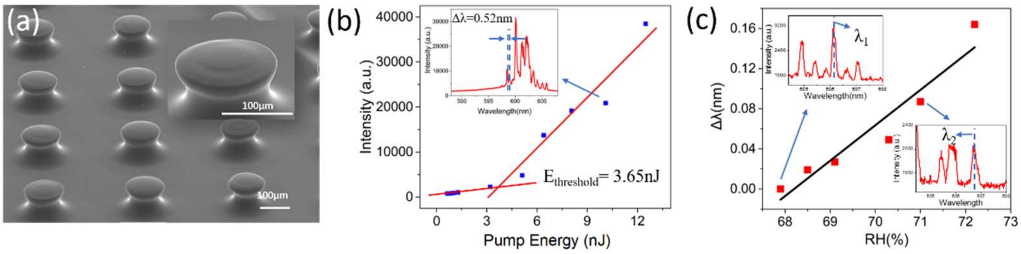

Fig. 2. (a) SEM images of polymer mushroom-like optical microcavities coated with gain layer. (b) Input-output curve for measurement of lasing threshold in air. The inset is the output spectrum at pump energy of 10.11 nJ. (c) WGM laser peak shift with the increase of RH. The left and right corner insets are output spectra at RH = 67.9% and RH = 71%, respectively.

Figure 2(a) shows the SEM images of 140.6 μm-diameter microcavities coated with gain layer. In Fig. 2(b), the input-output curve shows that the threshold of the microcavity laser is 3.65 nJ. It is shown in the inset of Fig. 2(b) that the lasing mode spacing Δλ is around 0.52 nm which matches well with the WGM mode spacing of the microcavity with 140-μm diameter. In Fig. 2(c), when RH increases from 67.9% to 71%, the tracked laser peak shifted from 606.633 nm to 606.720 nm. The experimental result showed that the WGM microcavity laser has a RH sensitivity of 35 pm/% RH.

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References

[1] J. R. Askim, M. Mahmoudi, and K. S. Suslick, "Optical sensor arrays for chemical sensing: the optoelectronic nose," Chem. Soc. Rev. **42**, 8649-8682 (2013).

[2] U. Bog, F. Brinkmann, H. Kalt, C. Koos, T. Mappes, M. Hirtz, H. Fuchs, and S. Kober, "Large-scale parallel surface functionalization of goblet-type whispering gallery mode microcavity arrays for biosensing applications," Small **10**, 3863-3868 (2014).

[3] X. Ouyang, K. Zhang, J. Wu, D. S. Wong, Q. Feng, L. Bian, and A. P. Zhang, "Optical micro-Printing of Cellular-Scale Microscaffold Arrays for 3D Cell Culture," Sci. Rep. **7**, 8880 (2017).

[4] Y. Zhang, Q. Zhang, X. Ouyang, D. Y. Lei, A. P. Zhang, and H. Y. Tam, "Ultrafast Light-Controlled Growth of Silver Nanoparticles for Direct Plasmonic Color Printing," ACS Nano **12**, 9913-9921 (2018).