Fabrication of binary phase grating on the fiber end by using two- beam interference lithography

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Micro and nano structures on the fiber ends have been developed for various applications such as wavelength division multiplexing[1], sensing, optical coupling[2] and beam shaping[3]. For photo-lithography applications previous researchers demonstrated directly writing by using an optical fiber[4]. By employing the technique of scanning near-field lithography, the resolution of writing structures could be <100 nm, which was enough for many applications. In this paper, an alternative method of directly writing binary phase grating (BPG) of sub-micron pitch on the facet of an optical fiber is demonstrated. Being capable of writing a few gratings at the same time, such method may be economical and time saving.

There have been demonstrated that structures on a fiber facet could be made by e-beam, focus ion beam, and photo-lithography[3]. We adopt the photo-lithography method because of its feasibility of mass production. The BPG was designed for 364 nm wavelength operation. According to simulation results, the optimized height and period of gratings were 270 nm and 728 nm, respectively. The height of BPG is the key factor to minimize its zero-order diffraction intensity; therefore, the thickness of coated resist is critical as we used it to serve as our phase change material. Two methods, spray[5] and spin[3] have been proposed to coat resist on the facet of a fiber. We utilized spin coating because it was easier to control the resist thickness by simply tuning the rotation speed.

Because the area of an optical fiber facet was too small (125 μm in diameter), the coated resist could not be uniformly flat due to surface tension of the resist. To enlarge the area of facet, a fiber adapter (2 mm in diameter) was fixed to the center of a holder, which was then fixed on the stage of a spin coater. First, the photoresist was spun on the fiber and then heated by a hot plate at 90 ℃ for 60 seconds. Finally, the BPG was fabricated by utilizing two-beam interference lithography at 364 nm wavelength from an argon-ion laser, and the resultant grating pattern is shown in Fig. 1.

We measured the 0, ±1 order of diffraction efficiency by coupling 364 nm light to the opposite end of the fiber with BPG. We observed ±1 order light was brighter than 0 order. The measured intensity ratio of ±1 order to 0 order light was about 2. The result is expected to be improved by e.g. better coupling efficiency, use of a suitable photonic crystal fiber, use of a more index-matched phase material, and fine tuning of the photoresist thickness.

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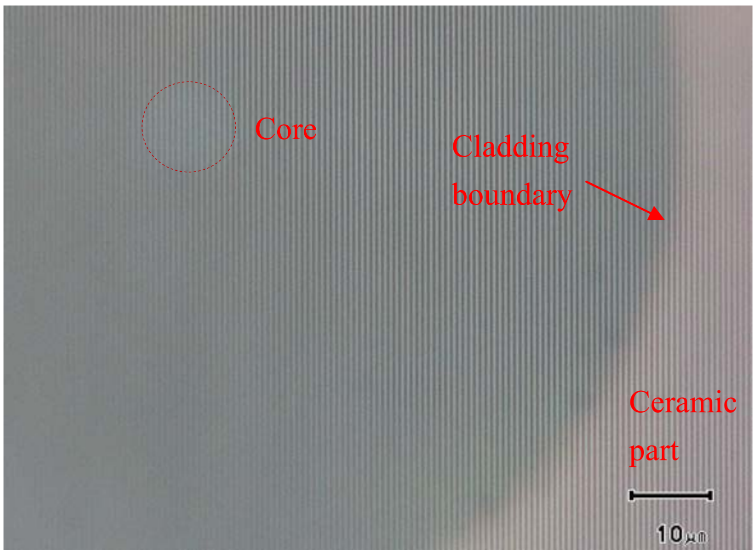

Fig. 1 Micrograph shows the BPG on the fiber end surface, covering core, cladding, and ceramic part; the period is about 720 nm.

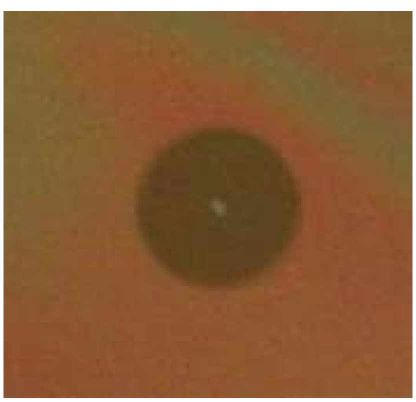

Fig. 2

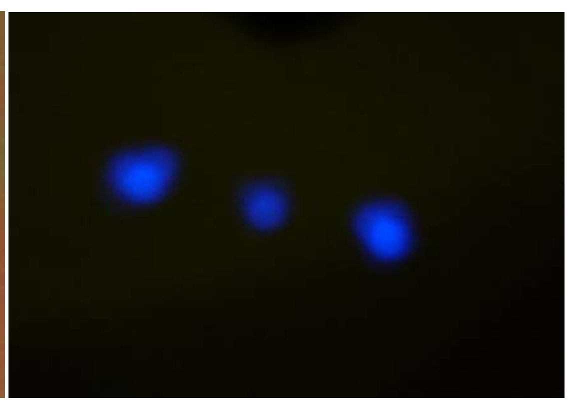

Fig. 3

Fig. 2 Micrograph shows the uniformity of the coated resist.

Fig. 3 Photograph shows that ± 1 order light is brighter than 0 order.