Soft Patterning on Cylindrical Surface of Plastic Optical Fiber by Sliding Roller-Imprinting

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We developed a sliding roller-imprint method to fabricate microstructures on the surface of plastic optical fibers (POF) without damaging them. To demonstrate this technology, we employed a special electroformed-Ni mold with a mirror image of a string of characters forming a word “MACROBEANS” engraved like a lattice, where the individual characters were composed of diffraction grating structures with their linewidths of 1 or 2 μm. Figure 1 shows that the color of each character string was changed slightly to cause different reflective properties depending on the kind of diffraction gratings. Using this mold, the cylindrical surface of a POF CK-10 (Mitsubishi Rayon), that comprised a 240-μm-diameter polymenthylmethacrylate (PMMA) core with a coat of a 5-μm-thick fluorine resin clad, was thermal-imprinted as shown in Figure 2. The upper part of the figure shows that the character pattern composed of diffraction grating structures with 1 μm linewidth was quite bright. The lower part of the figure confirms that only the cylindrical surface was patterned without causing any damage to the POF. The height of the convex mold pattern was 1.1 μm, and the depth of the concave imprinted pattern was approximately 1.0 μm.

In conventional thermal nanoimprint using a plane mold, the shape of the molding material is a film spread on plane substrates or a plate of the bulk. In the case of 3-D shaped molding material like the fiber, the shape is susceptible to some damage by a plane mold. We have designed a sliding roller-imprint method shown in Figure 3. A fiber tightly stretched between a sending and winding reel stations is sandwiched between two plane molds facing each other. The fiber is then rolled on the pattern sides of the two plane molds while remaining synchronized with the sliding motion of plane molds in opposite directions. The problem of twists in the fiber caused by the sliding roller-imprinting was solved by dynamically rotating the reel stations matching the rotation of the fiber. In addition, a contact force and a sliding speed were optimized.

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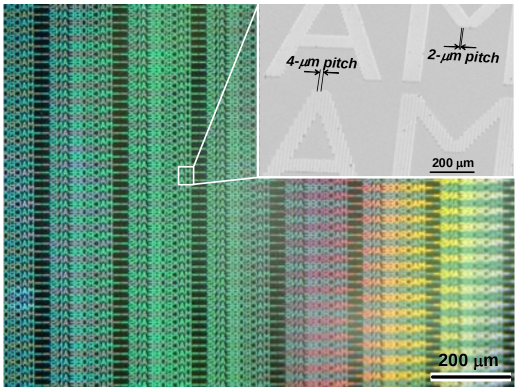

Figure 1: Optical micrograph of the character patterns in plane electroformed-Ni mold. The inserted figure is a SEM image of diffraction grating structures in characters "MA" observed at an inclined angle of 45^o.

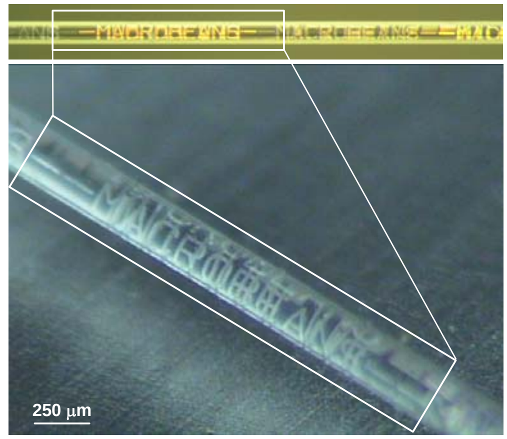

Figure 2: Optical micrographs of the character patterns with diffraction grating structures transferred from the plane electroformed-Ni mold to a cylindrical surface of POF.

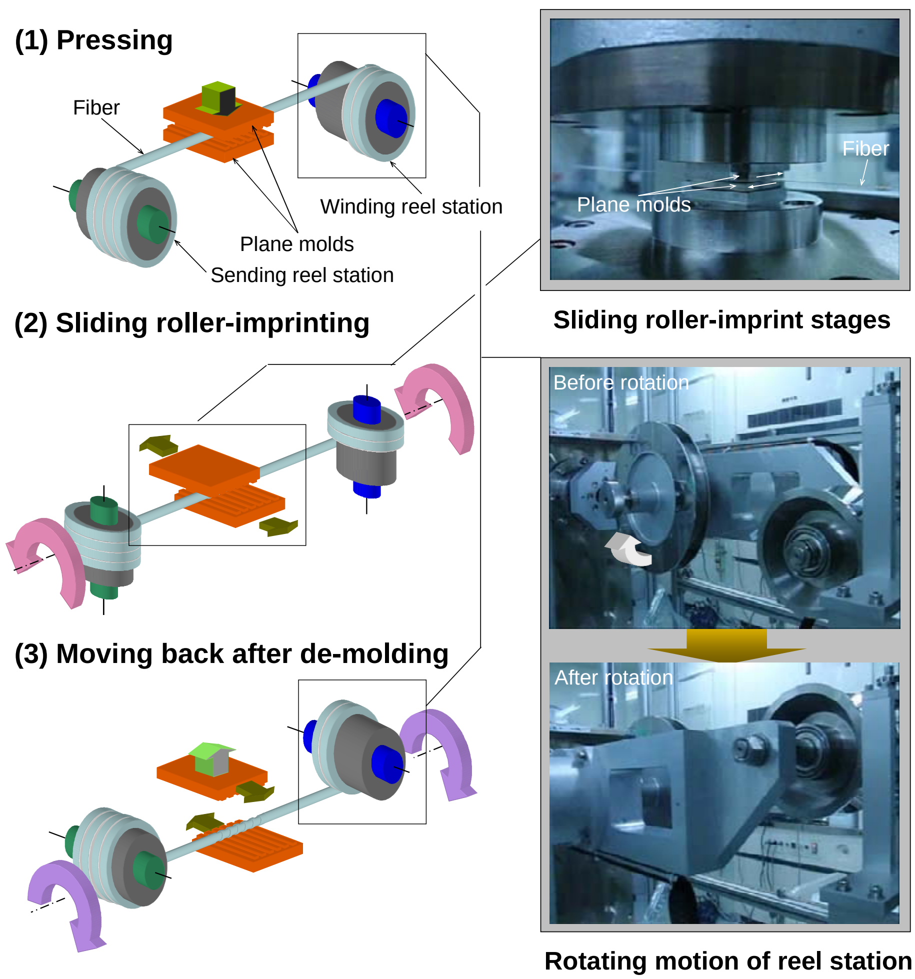

Figure 3: Patterning procedure on cylindrical surface of POF by a combination with sliding roller-imprint stages and 180-degrees-rotatable reel stations.