Control of Inclined Angle of Glass-like Carbon Mold by Defocus UV Exposure on Si Containing Photoresist

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We fabricated micro-patterns with inclined sidewalls in a glass-like carbon (GC) mold to thermal-imprint on a glass substrate, and succeeded to control its inclination angle. The technology comprised three features: 1) A Si containing photoresist with its etching tolerance higher than that of the conventional photoresist was used. 2) The inclination angle of pattern's sidewalls was controlled by a defocus UV exposure technique. 3) A GC substrate was etched to form a mold by using a Si containing photoresist structure with inclined sidewalls as a masking layer; the technique was also used to control the inclination angle of the trench's sidewalls in the GC mold.

A film of Si containing photoresist FH-SP3CL (FUJIFILM Electronic Materials) was spin-coated to a thickness of 840 nm on a polished GC wafer, followed by irradiating the film by a 700 mJ of ultraviolet (UV) light after passing through a reticle mounted on an Ultratech UV stepper 1500 MVS R-PC system. We input different focus-offset values to defocus the image in order to minimize the UV light intensities which then led to the formation of photoresist structures with sidewalls inclined at some desired angle (Fig. 1). In the next step, GC was etched by a mixture of O_2 and CHF_3 in a reactive-ion-etching (RIE) system Model RIE-10NRS (Samco), which then created a trench structure with inclined sidewalls according to the variations in local masking time. Next, using a thermal nanoimprint system ASHE0201 (Engineering System), the GC mold heated to 645 ºC in a vacuum was pressed against a Pyrex glass substrate at a contact force of 700 N for 10 min.

Figure 2 shows the inclined angles of pattern's sidewalls in each process. We compared 5-μm-diameter circular and 5-μm-width square dotted patterns (Fig. 3). When changing the focus offset values in the UV exposure from 0 to -12 μm, the inclined angle of FH-SP3CL photoresist microstructures ranged from 17 to 40 degrees. The range of inclination angles of GC molds became 6 to 17 degrees; and it expanded from 6 to 32 degrees in the thermal imprint on the Pyrex glass substrates. It seems that the corners of the square dots were etched selectively in the RIE process as compared with the case of the circular dots; the inclined angle then became large. On the other hand, because the corners of the square dots were not completely filled by the melted glass material in the thermal imprint process, the inclined angle was measured to be larger than would be otherwise.

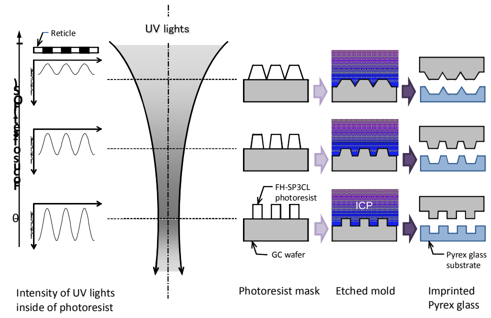

*Figure 1: Control method of inclined angle of pattern's sidewalls in GC molds by a combination of defocus UV exposure and reactive-ion-**etc**hing on a Si containing photoresist.*

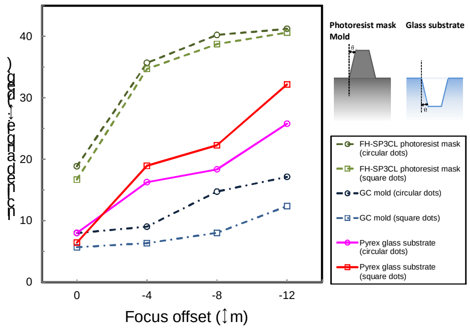

Figure 2: Relationship between focus offset values and inclined angles of FH-SP3CL photoresist masks, etched GC molds, and imprinted Pyrex glass substrates.

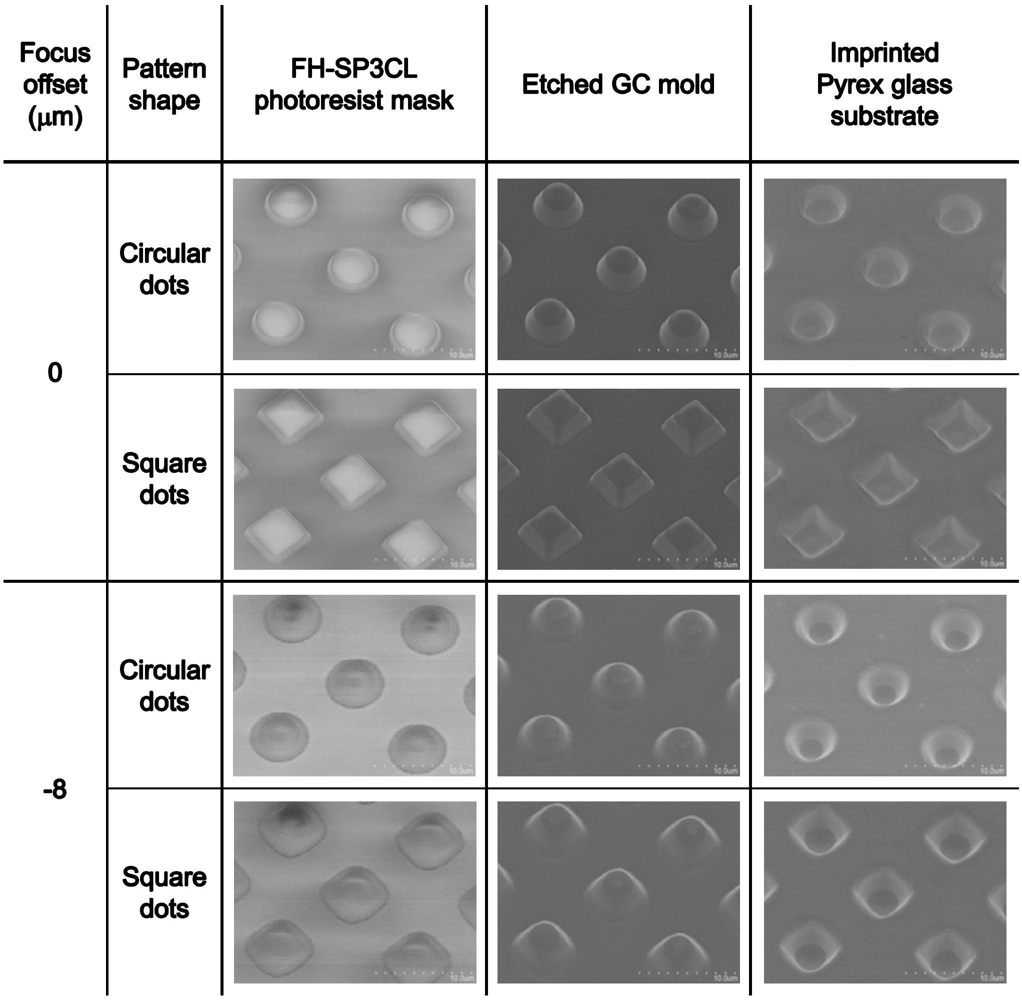

Figure 3: FE-SEM images of 5-μm-diameter circular and 5-μm-width square dotted patterns of FH-SP3CL photoresist masks, etched GC molds, and imprinted Pyrex glass substrates observed at an inclined angle of 30°.