Lithography Guided Fracture Induced Self-Assembly (G-FISA)

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FISA is a recently discovered phenomenon, where an initially flat featureless polymer sheet sandwiched between two flat plates *self-forms* a periodic grating as the two plates being separated [1] (Fig. 1). The period of the FISA grating is four times of the film thickness and its direction is normal to the separation direction. FISA is attributed to the competition between adhesion and elastic force in fracturing during the separation. Here we report a new FISA method, termed Guided Fracture Induced Self-assembly (G-FISA), where we put micropatterns on one of the two plates (rather than two flat, featureless plates) and use them to guide and modulate FISA. The study of G-FISA is also significant to nanoimpriting, since FISA patterns can be formed during the separation between the mold and the substrate, adding new features to imprinted surface.

In our experiment, a polystyrene film with different thicknesses (30-80 nm) was sandwiched between a patterned Si substrate (mold) and a flat featureless silicon substrate. The patterns on the mold are 1 μm pitch grating. The sandwich was pressed uniformly by Air Cushion Press (ACP™) of Nanonex NX-2000 Imprintor at 250 psi and 100 °C for 2 minutes, to ensure a good contact between the polymer film and the two plates, and an imprint of the mold into polystyrene film. The substrates were then separated at room temperature.

We observed two sets of grating patterns in the polystyrene: one set defined by nanoimprint mold, and another set coming from FISA. The period of the FISA grating is determined by the material thickness after the imprinting. The location and orientation of FISA grating are determined by the grating on the mold and the direction of the separation.

When the separation is normal to the mold grating, the FISA grating formed in parallel with the mold grating; one grating line per mold trench (Fig. 2). This is because that the FISA grating period is 380 nm (4 times of 95 nm polymer thickness), but each mold trench is only 500 nm wide, so only one grating line formed in each trench. The FISA grating line (200 nm wide) also aligned the edge of trench and located 150 nm away and in the center of the mold trench. The superimposition of the FISA grating to the mold-defined grating doubled the total grating frequency (inside the mold trench).

When the separation direction is changed to parallel with the mold-defined grating, the FISA grating was formed perpendicular to the imprinted grating (Fig. 3) and formed only inside of mold trench. This is because the polymer under the mold protrusion was too thin (<20 nm) to form FISA grating.

In G-FISA, nanoscale self-assembled patterns are achieved in a controllable manner under the assistance of lithography technique, and are formed using a mold with much larger features (hence lower cost). This technique may have applications in large area low-cost fabrication of sub-100 nm structures, such as nanophotonics, and 2-dimensional nanodevice fabrication.

[1] L. Pease, P.A. Deshpande, W. Russell and S.Y. Chou, to be published. L. Pease PhD Thesis, and P.A. Deshpande, PhD Thesis, Princeton 2005.

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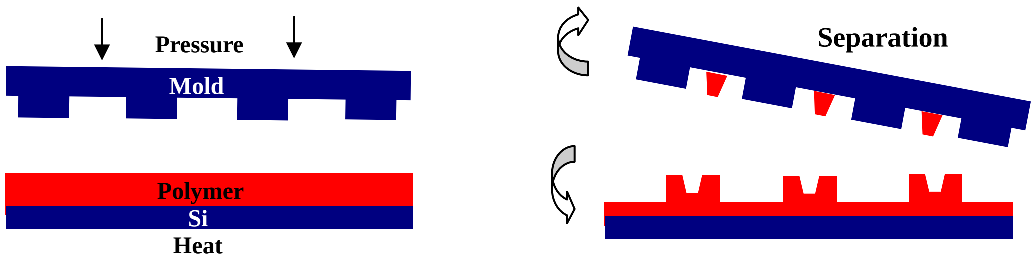


(a) (b)

Fig 1. Schematic of Guided FISA that doubles or triples a grating frequency. (a) A grating mold of period P is used to imprint a thin polymer film on a flat substrate. (b) As the mold being separated from the substrate at room temperature, FISA creates additional gratings in the resist that, depending upon the mold grating period and resist thickness, double or triple the grating frequency.

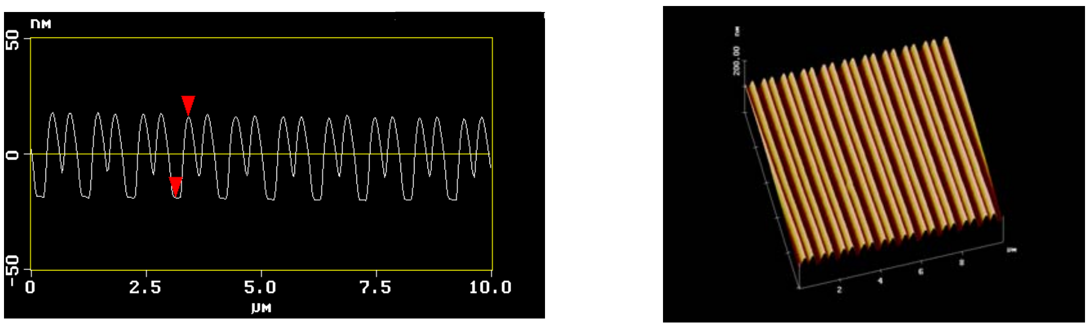
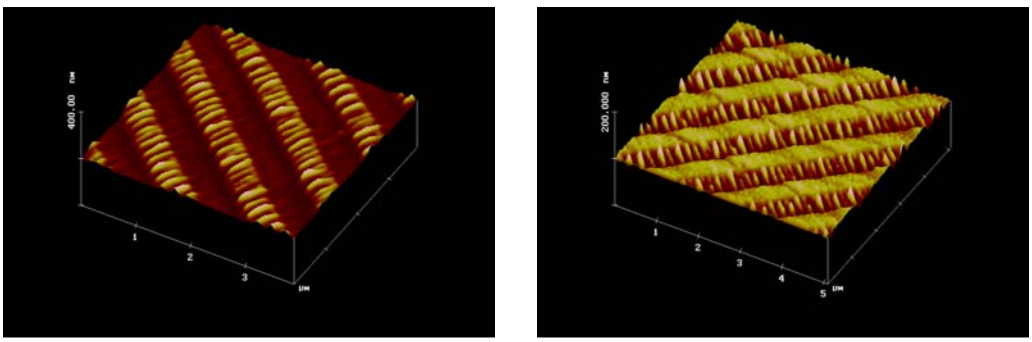


Fig. 2 AFM image shows two sets of grating formed on the substrate after imprinting with 1 µm period grating mold. The self-assembled grating pitch from FISA is 400 nm and 23 nm deep, doubling the grating period.



(a) (b)

Fig.3 AFM images show FISA grating perpendicular to mold grating, (a) Grating on the substrate; (b) complimentary grating on the mold. The pitch of the mold is 1 µm; the thickness of polystyrene film is 35 nm. The FISA grating pitch is 160 nm.