An Ultra-Stiff Stage for Imprint Lithography

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The high-resolution capabilities of imprinting and step and flash make these techniques strong contenders for the next generation lithography. Unfortunately, alignment remains an area of concern because it must be completed before the template is moved into contact with the wafer. The large forces on the template at contact, even for step and flash, place additional demands on the stiffness as well as the reproducibility of the template stage.

A prototype flexure stage has been demonstrated with extremely high transverse stiffness and relatively free motion in the vertical direction (Fig. 1). The prototype stage is based on a steel bar, 5 cm wide by 3 mm thick, and 60 cm long. The stage is bolted at each end to an optical table. It is kept in a horizontal plane by adjusting the bolts on the right hand side around a fulcrum. Unloaded, the resonant frequency of the stage is about 40 Hz (Fig. 2a), the oscillations decaying with about a 3 second time constant. However, the application of an in-plane compressive load reduces both the resonant frequency (Fig. 2b) and the force needed for vertical deflection (Fig. 3a). The compressive load is set at slightly below what is known as the Euler limit. Above the Euler limit the stage is unstable, snapping into a deflected state either above or below the median plane; at the Euler limit the restoring force for small deflections from the median plane approaches zero.

The motion of the stage was studied by passing a HeNe laser beam at 633 nm through a 2 µm period diffraction grating fixed to the stage. A 20X microscope objective projected an image of the grating onto a CCD video camera (Fig. 1). Frames from the camera were recorded on a VCR and analyzed off-line. A stop added to the microscope objective blocked the zero order beam, halving the effective period of the grating and greatly extending the depth of focus. The vertical motion of the grating was in a straight line to within the measurement accuracy of ± 3nm over a range of several hundred µm.

A system of weights and a pulley was used to apply horizontal forces at the midpoint of the stage, roughly parallel to its long dimension. The stage stiffness was measured as about 250 nm/kilogram of weight under compressive loading and 180 nm/kilogram of weight unloaded (Fig. 3b). As expected, the stage was much more compliant in the horizontal direction perpendicular to its long dimension, deflecting about 3 µm/kilogram of weight for both loaded and unloaded conditions.

Although this prototype is already quite stiff, far stiffer stages could be constructed using compressive loading and more optimal materials and geometries. For example, two relatively wide bars joined at right angles would provide high stiffness in all directions in the horizontal plane (Fig. 4).

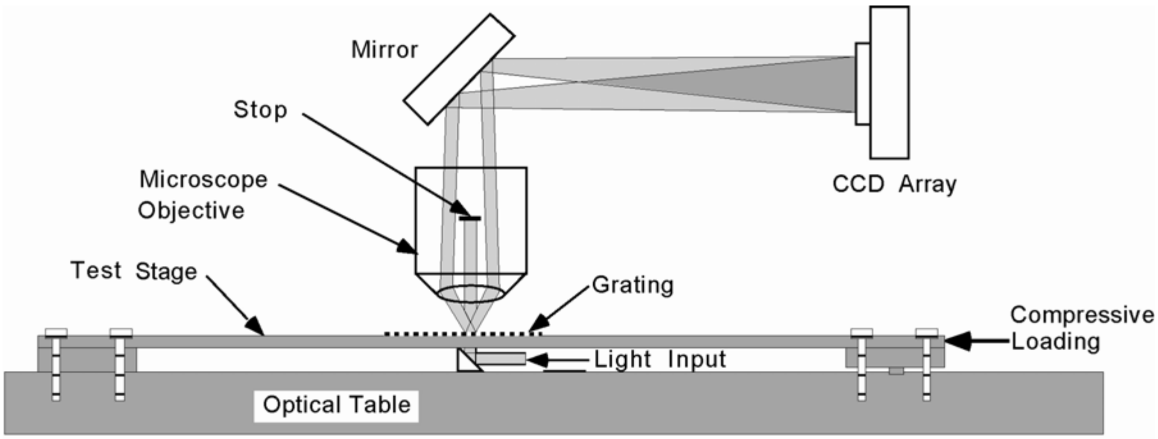

Fig. 1. Sketch of experimental apparatus (not to scale).

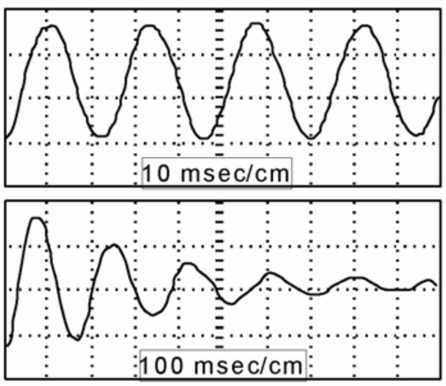

Fig. 2. Vertical vibrational response of uncompressed (top) and compressed (bottom) stages.

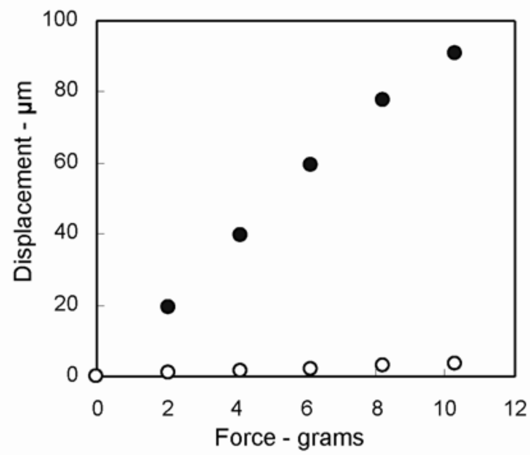

Fig. 3a. Vertical displacement vs. force for compressed (solid circles) and uncompressed (clear circles) stage.

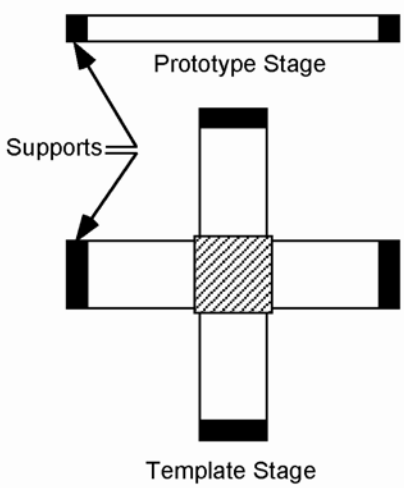

Fig. 4. Top views of the prototype stage (top) and a proposed template stage (bottom), to the same scale.

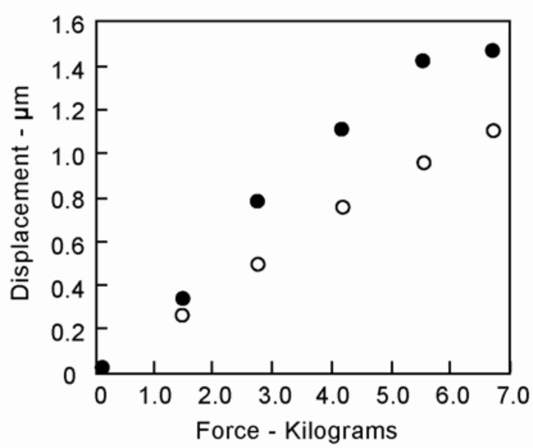

Fig. 3b. Horizontal displacement vs. force for compressed (solid circles) and uncompressed (clear circles) stage.