Lithography with nanometer precision on monster substrates

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For several decades interference lithography (IL) has served as a valuable laboratory tool for fabricating a wide variety of periodic patterns and devices. In the commercial world, however, its use has been confined to narrow niche applications such as patterning of spectroscopy gratings. While this has many reasons, a major limitation of traditional IL practice is that it scales poorly to large substrates, resulting in slow production rates and poor control of grating geometry (e.g., grating pitch, duty cycle, phase and depth). While several potential high-volume commercial applications for periodic structures have been identified, roll-to-roll processing will be required to meet volume and cost targets. For example, flat panel display and solar cell volumes are measured in square kilometers per year. For these applications, scaling IL to pattern large masters requires producing high quality patterns with high yield and hence low cost. Scanning-beam interference lithography (SBIL) is a new IL technique that breaks the scaling barrier. This technique utilizes a pair of beams to generate a small region of fringes on the substrate, which is then raster scanned to cover large areas. High speed electronics lock the fringes to the moving substrate. In this talk we will discuss the SBIL technique and how it was scaled to pattern substrates nearly a meter in size and well over 100 kg in mass, while achieving under 30 nm of phase error over the entire substrate (see Fig. 1). Special tools for cleaning, resist coating, lithography, metrology, and pattern transfer on large substrates will be described. We will also discuss a new SBIL technique called multi-level SBIL which has produced periodic patterns with pitches well below 100 nm on large substrates (Fig. 2).

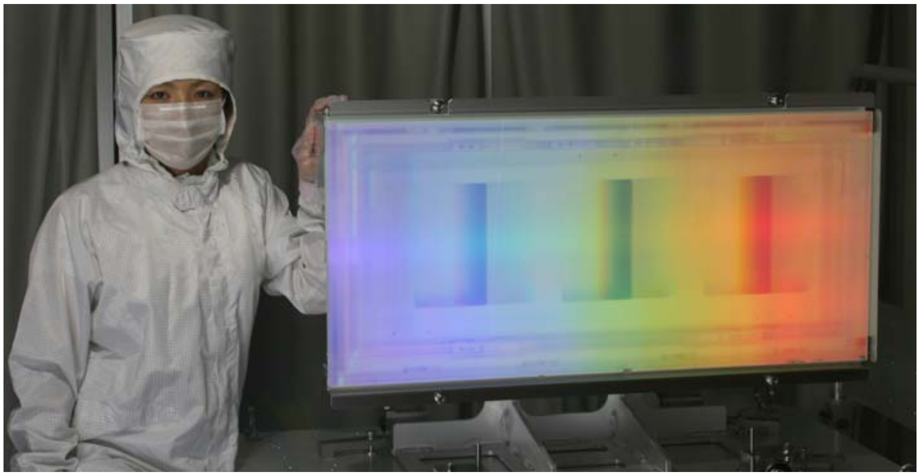
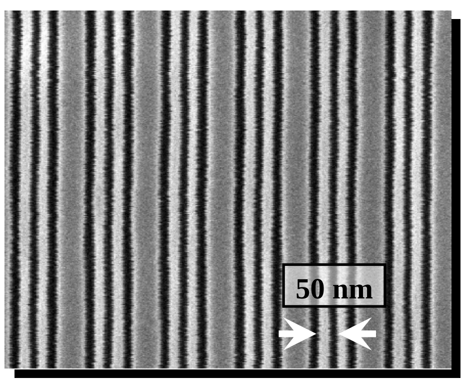
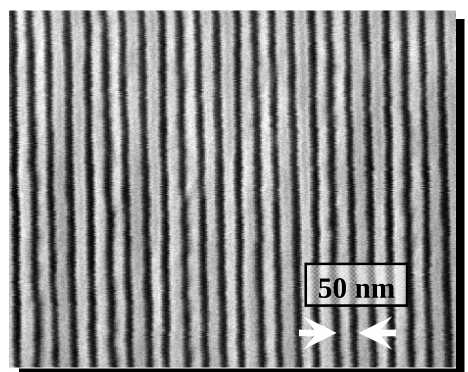


Figure 1. Photograph of a 0.5 x 0.91 meter diffraction grating patterned using the SBIL technique. The grating is used in fusion energy research at the Institute of Laser Engineering at Osaka University in Japan to provide high energy laser pulse compression. Similar gratings are used for fusion energy research in the USA, Europe and China. (*Photograph courtesy of Dr. Jitsuno Tanaka.*)



(a) Three lithography levels



(b) Four lithography levels

Figure 2. Electron micrographs of a 4X overlaid grating etched in silicon nitride after the (a) third and (b) fourth grating exposures. The final pitch is 50 nm (25 nm lines and spaces).