Subwavelength Moiré Index Lens-Array – Flat, Ultra-Thin, Large NA, and Patterned by Large Area Nanoimprint Using a Mold Formed by Multiple-Double-Nanoimprint

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Traditional micro-lens has a non-flat and thick structure, often low numerical aperture, and complex fabrication steps. Many modern technologies would have a need for a micron lens array that can be made ultrathin, flat, numerical aperture close to one, scalable to large area, and manufacturable at low cost. Here, we present a proposal and demonstration of a new ultrathin flat lens structure and its fabrication method, that meet all above five requirements. The new lens, termed "subwavelength Moiré Index lens" or SMIL, is a thin flat material layer where the gradient optical index is created using a binary subwavelength Moiré pattern that is a result of superpositions of two or more periodic structures (e.g., grating or grid). Fig. 1 shows a SNIL with a hole array Moiré pattern created in a thin dielectric material (e.g., glass, TiO2, or Si), forming a flat, ultra-thin (~100 nm) convex lens array. The Moiré pattern was formed using several superpositions of a basic periodic structure of 200 nm period. A concave lens array will be formed using the same Moiré pattern as in a convex lens, if the air hole and the dielectric material are exchanged. The SMIL shown in Fig 1 was fabricated using one-step nanoimprint using a 4" mold that was generated by multiple double nanoimprint (MD-NIL) of the basic period structure (generated from a master mold created by interference lithography) and etching. The focal length and the numerical aperture of a SMIL can be turned by controlling the Moiré pattern of the superpositions of the periodic structures, the thickness of the material, and material index. The details of the SMIL design, fabrication and performance will be presented.

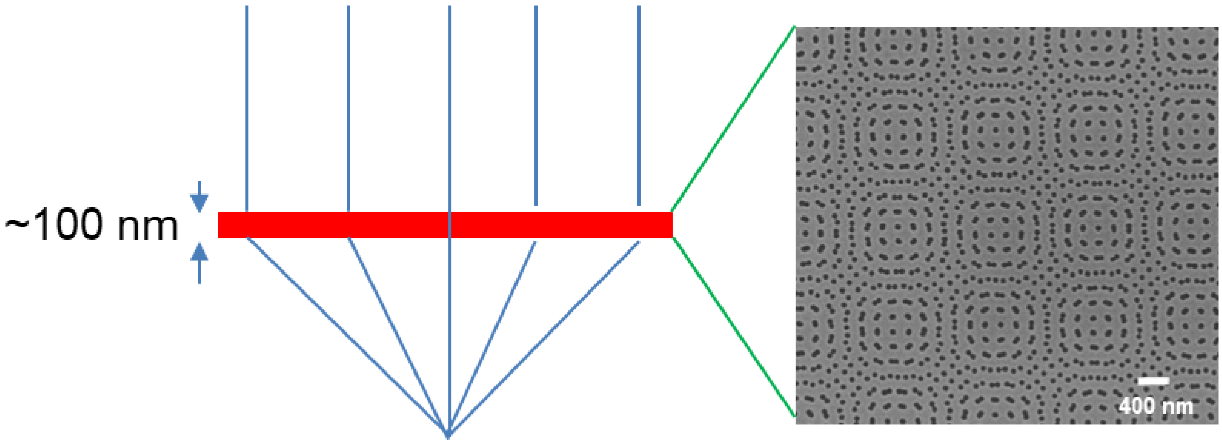

Fig. 1. (a) An illustration of a Subwavelength Moiré Index Lens-Array (SMIL), and (b) a SEM image of a SMIL made of a hole array Moiré pattern in a thin dielectric material, where the Moiré pattern comes from a proper superposition of several periodic structures (200 nm basic period).