518c Shear Alignment of Spherical-Phase Block Copolymer Thin Films

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Block copolymers spontaneously self-assemble into nanodomain structures: simple repeating patterns with a size scale controlled by the polymer molecular weight. Similar patterns are obtained when these block copolymers are deposited in layers a single nanodomain thick. Such thin films make excellent contact masks for patterning, where the block copolymer's nanodomain structure is faithfully reproduced in the inorganic material [1]. For example, we have used single-nanodomain-layer films of sphere-forming diblock copolymers to fabricate dense arrays of 20-40 nm metal particles [2] and III-V semiconductor quantum dots [3].

Block copolymer nanodomains ordinarily form a polygrain structure in both thin films and bulk, with a grain size which is typically microns at most. For applications where a dense array of near-monodisperse particles is required, this is satisfactory; however, other potential applications require orientational order or even translational order (such as ultrahigh-density recording media where each magnetic nanoparticle is individually addressed). Recently, we have developed methods to shear [4] these thin films at temperatures where both blocks are molten, producing orientational order extending over centimeters, and with markedly improved translational order (reduced density of dislocations). The shear may be imparted by a solid (a rubber pad dragged across the film surface) or a viscous fluid (silicone oil filling the gap between the supported film and a rotating parallel plate). A single-layer film shows no alignment, due to the mechanical isotropy of a hexagonal lattice. However, films which contain two or more layers of nanodomains can exhibit excellent alignment when sheared under the proper conditions, with all grain boundaries eradicated from the sheared region (with areas of square-cm or more). The top layer can be removed with a non-selective reactive ion etch to generate a template suitable for patterning.

Transmitting the shear stress from a rotating plate through a viscous fluid applies a gradient of shear stress to the film: zero at the rotation axis, maximum at the edge of the plate. Examination of the supported film after such shearing permits rapid identification of the conditions, especially stress, which are necessary to for alignment. We find that a threshold stress is required to achieve the limiting quality of alignment, where all grain boundaries are eliminated; this stress decreases as the block copolymer's order-disorder transition temperature is approached.

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