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Abstract

Small amplitude oscillatory shear forming is a technique that improves the performance of nanoimprint lithography by amplifying shear flow in narrow, squeezed geometries created during melt molding or glass forming of supported polymer films. To date, the technique has only been demonstrated for single micrometer-scale contacts representative of single features on wafer-scale nanoimprint stamps. In this work, we demonstrate scaling up of small amplitude shear forming to realize micrometer and nanometer feature patterning of thermoplastic polymer films over macroscopic centimetre square areas at temperatures in the vicinity of, and below the glass transition. By the use of a small amplitude (typically 5-10% the smallest pattern feature dimension) lateral oscillatory shear strain at a 10 kHz frequency superposed during the normal motion of a nanoimprint mold, we are able to achieve high fidelity pattern replication in PMMA at temperatures as low as 35° C below its glass transition temperature. We further show that the technique is effective to pattern both bulk polymer surfaces and supported thin films, with samples as thick as 50 µm and as films as thin as 40 nm being successfully patterned. We demonstrate enhanced pattern fidelity using line-pattern imprint molds of 4 µm pitch and 35 nm relief, as well as an assortment of other geometries. For 800 nm PMMA films, a 40% reduction in the residual layer thickness at 100° C was achieved by the addition of shear strain. No feature distortion is observed due to the oscillatory motion of the mold. The technique is particularly advantageous for large scale features and cavities, as well as high aspect ratio geometries, as the high speed lateral motion of the mold features acts to cyclically pump material into areas where stresses generated by the normal motion of the mold will not suffice.