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Dynamic behavior in self-assembly process of cylindrical phase PS-*b*-PMMA block copolymer

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ABSTRACT

Self-assembly through phase separation in block copolymers (BCPs) thin films represents an attractive route to create spontaneously ordered patterns at the sublithographic range. The cost effectiveness, the fast parallel processing time as well as the compatibility with the standard microelectronics technologies make it among the most promising techniques to meet the ever challenging feature size requirements in nanotechnologies. In the present work, we investigate the behavior of cylinder forming poly (styrene-b-Methyl-Methacrylate) PS-b-PMMA self-assembly on a chemically neutralized 300 mm Silicon wafer. The effects of the process parameters such as the annealing temperature and time, the film thickness, and the BCPs periodicity on the holes formation after PMMA removal were studied in systematic fashion using statistical analysis of the Critical Dimension- Scanning Electron Microscope (CD-SEM) images,focusing mainly on the Critical Diameter (CD) and circularity of holes. In particular, it was found that both (CD) in the narrow range of 10–15 nm and a hole circularity of (0.8–0.9) in excess of 96% can be achieved on the whole wafer under appropriate processing conditions. The obtained results were correlated to the self-assembly process and shed some light on the dynamic of the phase separation process of BCPs. The level of reproducibility and control achieved on a 300 mm silicon wafer, hold a promise for future applications in nanotechnology.

1. Introduction

Self-assembling (S-A) soft materials have realistic potential for manufacturing nanodevices at future technology nodes. BCPs are a class of self-assembling materials that segregate on nanometer length scales, making them ideal for emerging nanotechnologies [1–3], including many applications in nanotemplating [4–8]. These applications require the use of BCPs in thin film geometries (< 100 nm thickness), where self-assembly is strongly influenced by different parameters. The simplicity and cost-effectiveness of the spontaneous BCP self-assembly process is attractive and holds promise for applications in nanolithography [9–12], with demonstrated capabilities in the fabrication of nanoscale devices [1]. Specifically, the use of cylindrical phase BCPs has been demonstrated for printing the capacitor layer of dynamic access memory devices [13–15]. PS-*b*-PMMA is a promising choice for nano-lithographic applications since the surface energies at the PS/air and PMMA/air interface are nearly equal under typical thermal annealing conditions [16]. This allows for easy and therefore low-cost processing. Moreover, the nanodomains of PMMA can be degraded by radiation and then removed with an organic solvent leaving PS as etch mask. Many researches have contributed to provide an understanding of block copolymer self-assembly, beginning with the characterization of bulk morphologies using the Flory-Huggins interaction parameter (χ), degree of polymerization (N), volume fractions (f) and chain architecture [17].

In thin films, where the interfaces strongly affect the final nanoscale morphology, commensurability between the film thickness (t) and the natural period (L_0) along with polymer-surface interactions can influence both the morphological symmetry and the orientation [18]. Several studies based on the ordering kinetics and morphology evolution in BCP materials have been described during the past. Perpendicular orientation of the nanodomains in cylindrical morphologies can be achieved by different methods such as surface modification, strong electric field, and solvent annealing. Important progress has been

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