Graphoepitaxial Directed Self-Assembly of a Gyroid-Forming Triblock Terpolymer in Thin Films

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Block copolymer self-assembly is a technique widely utilised to provide a sacrificial template for preparation of nanostructured metals, which find widespread application in devices for optical metamaterials and electrodes for batteries. However, the spontaneous self-assembly process suffers from a lack of control and long-range order, through numerous grain boundaries between domains. It is an active area of research to facilitate the formation of larger domain sizes, with fewer defects and a controlled orientation with respect to the substrates, using chemically or topographically patterned substrates giving rise to a phenomenon known as directed self-assembly. In this way, the quality of devices manufactured from nanostructured metals will be improved.

This work provides novel evidence of directed self-assembly in a gyroid-forming system with the {110} plane alignment, using topographically patterned silicon substrates. To achieve this, thin films of the ISO triblock terpolymer were spin-coated onto topographically patterned silicon substrates and solvent-vapour-annealed to facilitate formation of the gyroid phase, showing the {110} plane. Characterisation of the surface pattern morphology and domain orientations was performed using atomic force microscopy, examining the morphology over and within trenches of different depths and widths. Fast Fourier transforms of image sections revealed the domain orientation and provided a quantitative measure to highlight the extended preferential alignment within the confinement of the trench walls, without defects such as disclinations.

The most promising trench patterns to show extended directed self-assembly were those with the narrowest trench widths, namely 390 nm wide (in the range of 11 unit cell widths) and 30 nm deep (approximately 1 unit cell depth). Promising yet not-so-substantial results were also observed for trenches in the same width range (namely 310 nm or 9 unit cell widths) but with depths of approximately 90 nm (around three unit cell depths). Convincing evidence for larger domain sizes was lacking for many cases of wider trenches of up to 5 μm in width.

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