Line-Scan Sequential Lateral Solidification of Prepatterned Si Films

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Abstract:
Melt-mediated crystallization of prepatterned Si films represents an established route for manipulating the microstructure of the films. Typically, solidification of strategically patterned Si films has been performed to obtain large-grained or single-crystal regions for producing high performance devices. In contrast to such investigations, this paper proposes—and evaluates the applicability of—crystallizing prepatterned Si films with the primary aim of improving the apparent uniformity of resulting transistors. Specifically, we have performed directional sequential lateral solidification (SLS) of prepatterned Si films as a way of ultimately delivering high-mobility/high-uniformity devices that are desired for producing AMLCDs, AMOLED displays, and 3D integrated circuits.

Previous investigations have demonstrated that directional SLS can produce high-mobility-enabling Si films that, however, are recently found to contain physically distinct regions with varying densities of planar defects and/or crystallographic orientations [1]; we presently view such microstructural details, which are apparently quite innate to the method, as the main reason behind these high-mobility transistors exhibiting relatively poor device uniformity. By physically confining such a microstructurally distinct region within a narrow stripe of Si and by placing a multiple number of such stripes within the active channel region of a device, the approach proposed in this project can potentially substantially improve the apparent uniformity of the devices (without affecting the high-mobility character that arises from the directionally solidified microstructure).

Summary of Research:
The samples consisted of 100 nm thick Si films on SiO$_2$ coated Si wafers. A 1.7 µm oxide was formed by thermal oxidation at 1100°C for 400 minutes. The Si film was formed via low pressure chemical vapor deposition (LPCVD) process at 600°C for 17 minutes. The patterns consisted of a matrix of lines with varying widths with the smallest line width being 50 nm and the largest width being 1 µm. The patterns were created via electron beam lithography writing directly onto a 100 nm thick poly(methyl methacrylate) mask using the Leica VB6-HR e-beam lithography system.

The SLS irradiation system consisted of an excimer laser (308 nm wavelength, 30 nsec pulse duration), projection optics, and a sub-micron precision translation stage. One motivation for this research was to investigate if SLS could be readily achieved for very narrow patterns without taking precautions to avoid damage. Characterization of the irradiated stripes via atomic force microscopy, scanning electron microscopy, and electron backscatter diffraction (EBSD) measurements, reveal that the patterns can indeed be SLS processed. It can be seen that the processed lines form a bi-crystal directional microstructure.
The cause of this formation is thought to result from the interface-curvature stabilized solidification. As the SLS process is carried out, the corners and edges of the stripe are cooler because of enhanced cooling rates into the substrate. Therefore, when the Si is melted, the edge of the liquid-solid interface develops a rounded shape. As a result of this phenomenon, edge grains grow laterally towards the center of the stripe leading to microstructure seen in Figure 1.

References: