Pyrolyzed Carbon As a True Grayscale Lithography Mask

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Despite decades of promise, grayscale contact lithography remains a niche fabrication method. Part of this may be due to the inherent complexities of grayscale pattern transfer, but some of the slow progress may also be attributed to the lack of rapid affordable options for creating high fidelity grayscale masks. The recent emergence of direct write, multi-photon lithography makes grayscale lithography possible, however the serial nature of these direct write approaches do not scale well to high volume manufacturing. Here we demonstrate the conversion of 2.5D grayscale patterns written via multi-photon lithography into true grayscale masks for contact lithography via pyrolysis. Fig. 1 shows an example of the conversion from digital data to carbon mask. The grayscale digital data on the left was converted to height information and a commercial gray-scale lithography printer (2GL; Quantum X Align, Nanoscribe) was used to create a 2.5D version of the image in photoresist (IP-S) on a fused silica slide. The slide was pyrolyzed at 900 °C in an Ar/H ambient, resulting in the carbon grayscale mask on the right. The image of the carbon mask is approximately 250 micrometers across and shows a slight reduction in contrast but otherwise maintains remarkable image fidelity. Fig. 2 shows an optical microscope image of preliminary work using the carbon mask as a contact lithography grayscale mask. The grayscale exposure/develop parameters are not optimized in this image, leading to the grainy appearance, but fine features are still apparent. We present a thorough analysis of the fabrication details and physical transformation of the image converting from the ~8 micrometer thick 2.5D resist pattern to the ~ 20 nm thick carbon image.

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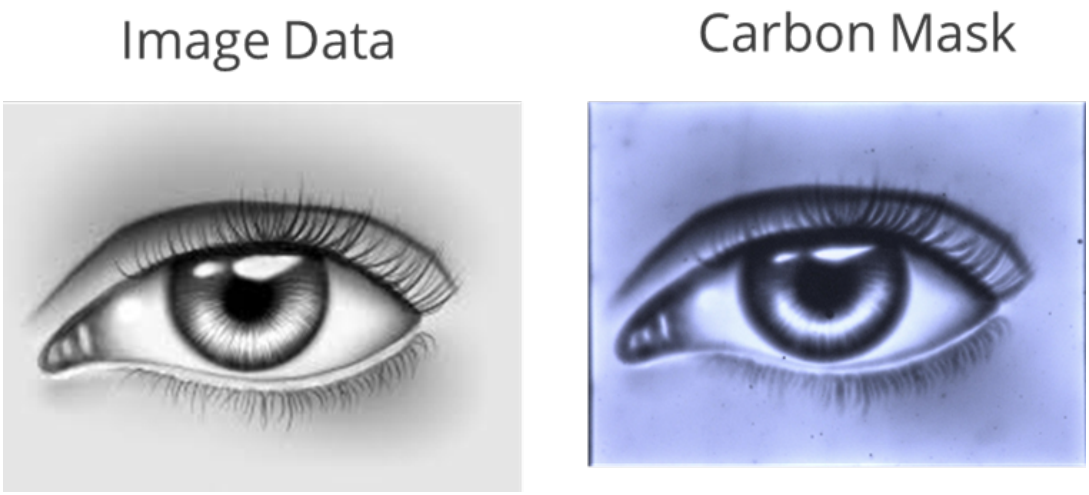

Figure 1: (Left) digital grayscale image data. (*Right*) *Optical microscope image of carbon mask after pyrolysis of 2.5D pattern.*

Figure 2: Grayscale contact i-Line lithography using carbon mask. AZ4330 resist (image flipped for comparison to mask).