Advanced metrology for extreme ultraviolet (EUV) mask blank defect reduction

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One of the top challenges for the commercialization of extreme ultraviolet (EUV) lithography is the production of defect-free mask blanks. The identification of defect sources and the thorough characterization of these defects are essential to determine mitigation solutions. Sub-100nm defects impose challenges to current conventional metrology techniques. The Mask Blank Development Center (MBDC) at SEMATECH has a comprehensive metrology strategy to address defects with a core size larger than 20 nm to obtain solutions for defect-free EUV mask blanks. In this paper, the rising issues with metrology of increasingly small EUV mask blank defects will be outlined. Further, SEMATECH's approach and existing capabilities, including a state-of-the-art metrology toolset to analyze EUV mask blank defects will be illustrated. These capabilities include high resolution transmission electron microscopy (HR TEM) and Auger electron spectroscopy (AES) which enables SEMATECH to study nanoscale defects. HR TEM provides the ultimate resolution in imaging and spectroscopy aiding in defect mitigation by revealing both the location and composition of a defect. The effect of disruption within the multilayer can be imaged to precisely determine the total phase change at the defect location providing critical information for defect printability studies. The TEM capabilities at SEMATECH are enhanced with other analytical electron microscopy techniques including energy dispersive x-ray spectroscopy (EDS) and electron energy loss spectroscopy (EELS) for composition data and tomography for 3D reconstructions of defect profiles. These methods provide superior analytical power compared with similar techniques in traditional secondary electron microscopy (SEM). Complementary to the HR TEM capability at SEMATECH is the newly established Auger tool which can run a standard 6-inch mask blank and is already providing important information on sub-100 nm defects. Comprehensive characterization results using HR TEM methods and AES on EUV mask blank defects will be presented.

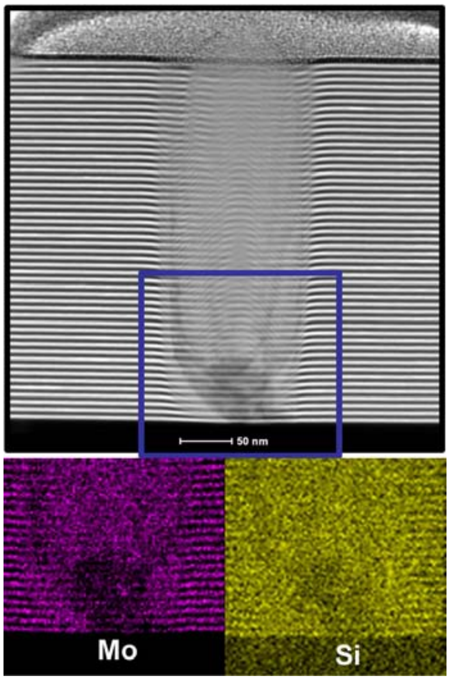

Figure 1. Top: STEM image of a particle-type defect on the substrate and the subsequent multilayer growth on top of it. STEM imaging provides detailed information on the ML disruption. Below: EDS elemental map demonstrates the ability to find shape, position, and composition of defect.

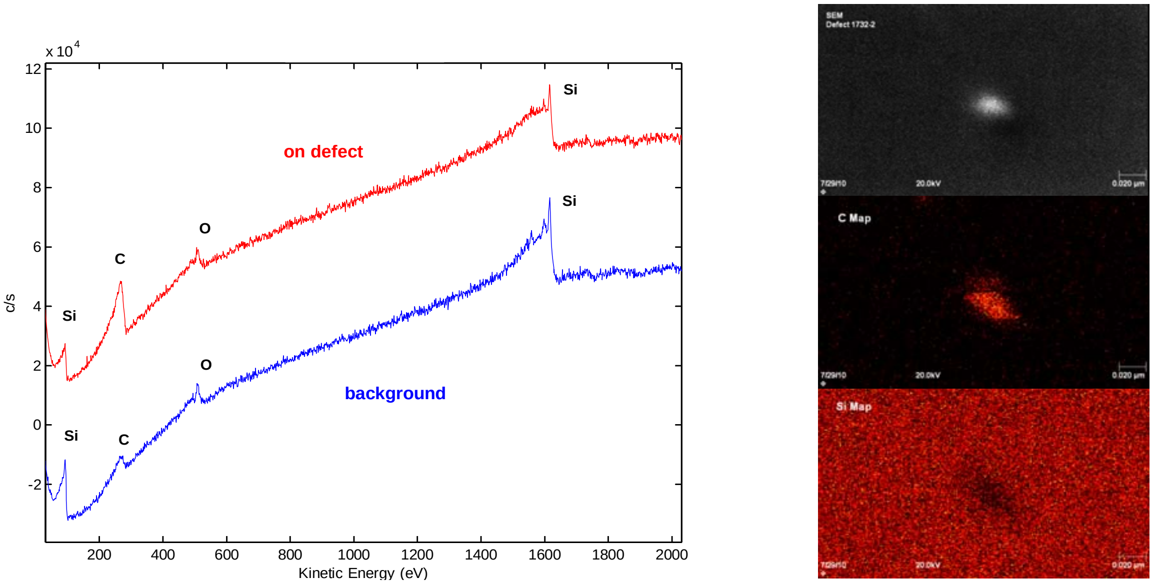

Figure 2. Left: Auger spectrum on 20 nm carbon defect on an EUV substrate. Right: The SEM image and elemental maps by AES identifies the defect as carbon and demonstrates the tool’s capability down to a 20 nm core defect.