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Variable Pressure/Environmental SEM a Powerful Tool for Nanotechnology and Nanomanufacturing

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Instrumentation and metrology are integral to the emerging nanotechnology enterprise, and have been identified by the U. S. National Nanotechnology Initiative (NNI) as one of a number of critical nanotechnology areas.[3] Instrumentation and metrology crosscut all the NNI Grand Challenges, and are both vital to the success and commercialization of nanotechnology. Advances in fundamental nanoscience, design of new nano-materials, and ultimately manufacturing of new nanoscale products will all depend to a great degree on the capability to accurately and reproducibly measure properties and performance characteristics at the nanoscale. It is imperative that a strong measurement and standards infrastructure be developed to support this work and the developing nanomanufacturing industry. Decades of nanoscience research have led to remarkable progress in nanotechnology as well as an evolution of instrumentation and metrology suitable for some of the nanoscale measurements. One example of today's practical nanotechnology is the integrated circuit production with circuit structures less than 100 nm in size. This and other technologies need the best possible instrumentation to reach their full potential. Consequently, today's suite of metrology tools has been designed to meet the needs of exploratory nanoscale research, and new techniques, tool, instruments and infrastructure will be needed to support a successful nanotechnology industry manufacturing commercial products.

Variable pressure/environmental scanning electron microscopy is one of the tools that has recently moved to the forefront as one method which is especially well suited to imaging and metrology for nanotechnology. Variable pressure/environmental SEMs have been successfully used in a number of biological, pharmaceutical and food applications and most recently to investigate binary and phase-shifting chromium on quartz optical photomasks with remarkable results (Fig.1). These masks are very susceptible to charge build-up under the electron probe of SEMs. In addition, this methodology was also applied to patterned ultraviolet (193 nm) photoresist structures. The application of this methodology to semiconductor metrology is relatively new. This is due to the fact that variable pressure SEM instrumentation equipped with high-resolution, high-signal, thermally-assisted field emission technology in conjunction with large chamber, stage and sample transfer capabilities are only recently becoming available.

The variable pressure SEM methodology employs a gaseous environment around the sample to help diminish the charge build-up that occurs under irradiation with the electron beam. Although very desirable for the charge reduction in many biological, pharmaceutical and food applications, this methodology has not been employed for semiconductor photomask or wafer metrology until just recently. This is a relatively new application of this technology to this area, and it shows great promise in inspection, imaging and metrology in a charge-free operational mode. For accurate metrology, high-pressure SEM methodology also provides a path that minimizes, if not eliminates, the need for charge modeling. Modeling of the electron beam interaction and the signal generation is still needed in order to understand the full derivation of the signal and work is progressing in that area, as well.

It is felt by workers at the National Institute of Standards and Technology that this methodology could ultimately provide a solution to accurate photomask metrology in the SEM. To that end, a "custom" variable pressure instrument is currently being constructed which utilizes a high brightness thermal field emission electron gun, 300 mm capable sample chamber and an accurate laser interferometer stage with 150 picometer resolution. This paper presents some of the results in the high-pressure SEM metrology of photomask and photoresist structures and discusses other nanotechnology applications.

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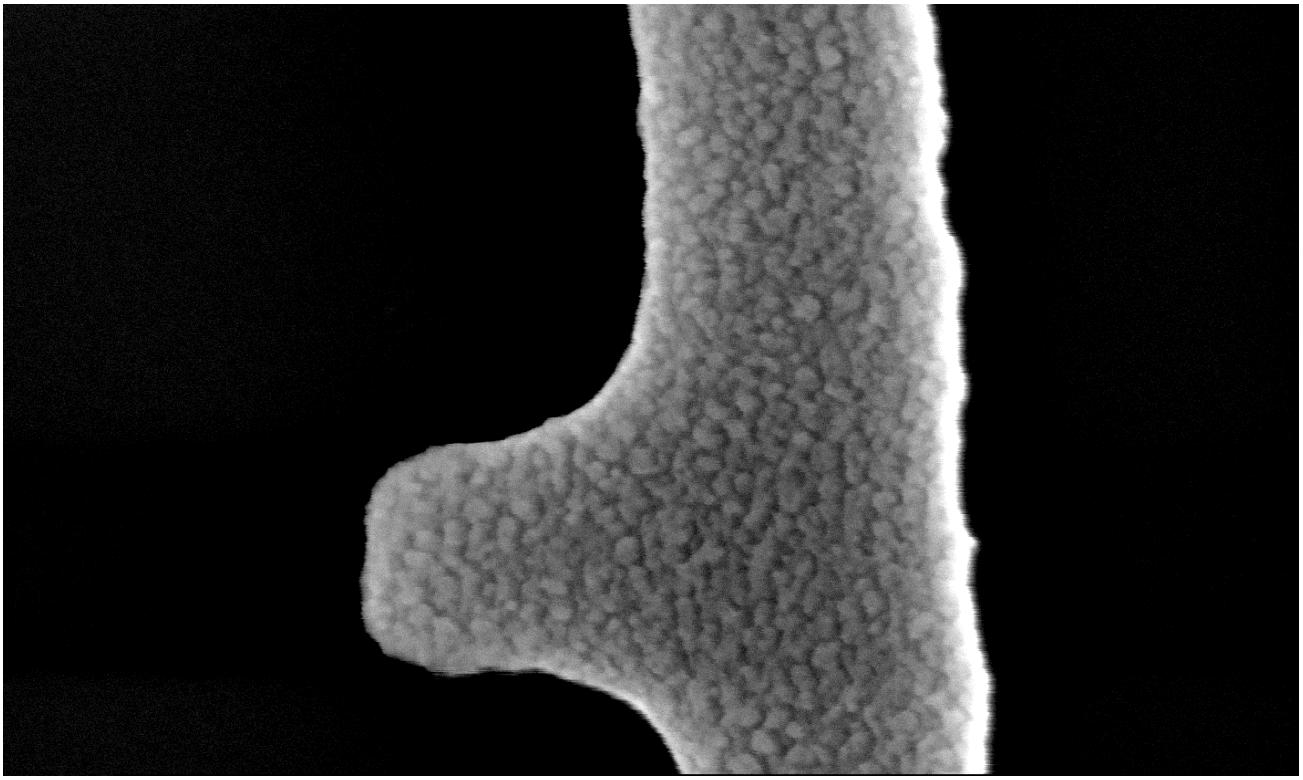

Fig. 1. High magnification images of chromium lines on quartz viewed in a variable pressure SEM at 142.7 Pa (1.07 torr); 9 kV accelerating voltage; 0^0 tilt; Field width = 1.3 μm. The image clearly shows the chromium grain structure which leads to undesirable line edge roughness limiting the quality.

References

[1] Contribution of the National Institute of Standards and Technology, not subject to copyright.

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[3] NNI Interagency Workshop on Instrumentation and Metrology for Nanotechnology 2005 available from the National Nanotechnology Coordination Office or downloaded from: www.nano.gov.

[4] Certain commercial equipment is identified in this report to adequately describe the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment identified is necessarily the best available for the purpose.

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