Understanding Imaging Modes in the Helium Ion Microscope

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Ions launched from a single protruding atom form the imaging probe of the helium ion microscope. As a consequence, the helium ion microscope is capable of image resolution approaching the atomic scale. To date, using secondary electron (SE) imaging mode, the microscope has demonstrated 0.24 *nm* image resolution. It is recognized as equally important how the beam interacts with the sample. These interaction dynamics provide the sample information that is available in various imaging modes. These image modes have been described and illustrated previously[1,2]. Recent investigations are gaining us a better understanding of the nature of these interactions and what they mean for the image information provided. In secondary electron imaging, for example, the surface sensitivity is attributed to the very low mean energy in the SE spectrum. The mean recoil energy transferred by the incident helium ions to the ejected orbital electrons on a typical sample has been shown to be around 2 *eV*. The mean free path of a 2 *eV* electron in a conducting material is sub-nanometer. As a result, helium ion microscope SE mode images show high resolution of only the top layer of the sample[3]. As a second example, voltage contrast imaging shows the ability to see both buried structures and to probe the conductance to ground of surface contacts. It is found, however, that the prominence of these two types of contrast vary oppositely with beam energy, yielding information about the nature of the interactions that give rise to them. Transmission ion imaging can yield information about material density, atomic number, and grain structure. It is possible to capture top-side SE signal, bright field signal, and dark field signal from a given sample simultaneously. There is no diffraction regime in the transmitted signal. Figure 1 shows a transmitted ion image of a semiconductor device. This bright field image shows superior material contrast between the nitride spacers (indicated by arrows) and the oxide, as compared to TEM.

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[1] L. Scipioni, L. Stern, and J. Notte, Microscopy Today 15(6) (2007), 12
[2] L. Scipioni, L. Stern, J. Notte, S. Sijbrandij, and B. Griffin, Adv. Mat. Proc. 166(6) (2008), 27.
[3] K. Ohya, T. Yamanaka, K, Inai, and T. Ishitani, SPIE Lithography Asia – Taiwan, 4-6 November 2008.

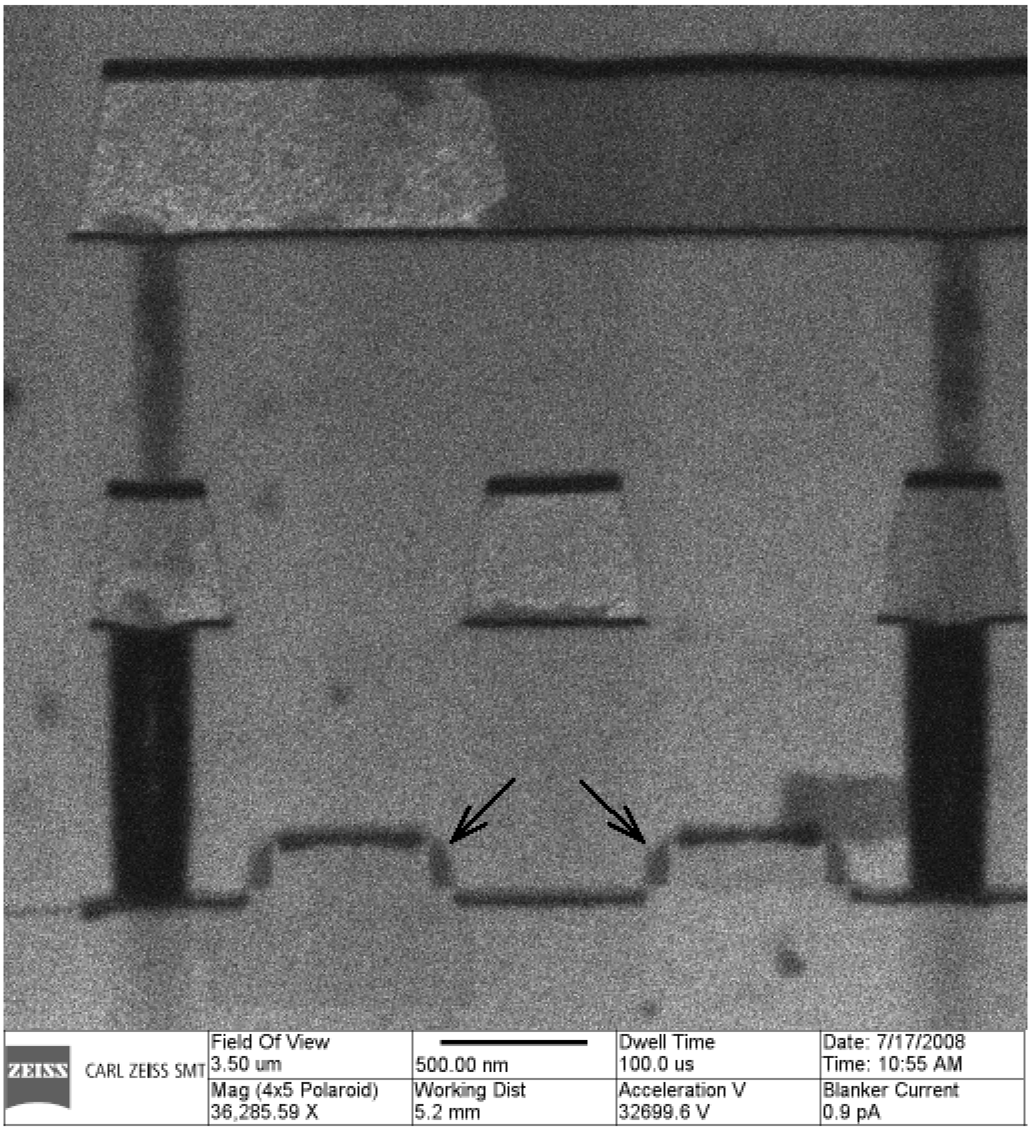

Figure 1. Transmitted ion brightfield image of semiconductor device showing gate area and first few metallization levels. Arrows point to silicon nitride spacers. FOV = 3.5 um