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A New Detector for Backscattered Helium Ions in the 30 keV Energy Range

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The recently introduced ORION helium ion microscope can provide high resolution images (0.5 nm resolution) with contrast mechanisms that are unique and complementary to those provided by traditional electron microscopes [1]. The images can reveal heretofore unseen structural and compositional details in samples, which make users curious about what they are seeing. However, unlike an electron beam, the helium ion beam does not produce enough characteristic X-rays which might otherwise be used for materials analysis. Instead, an alternative analysis capability has been developed which relies upon measuring the energy and angle of backscattered helium atoms [2].

The scattering of helium atoms from surfaces has long been used as a technique for understanding material composition. One century ago, in 1909, it was Geiger and Marsden who used 7.7 MeV helium nuclei to interrogate a sample – the experiment that led Rutherford to a new understanding of the structure of the atom [3]. Their experiment gave rise to the present day technique of Rutherford Backscatter Spectroscopy (RBS), a method used for ascertaining elemental composition and depth distributions. At lower energies, ~100 keV and ~5 keV, helium ions are also used for medium and low energy ion spectroscopy (MEIS and LEIS) [4]. While valuable on their own, these techniques cannot provide high resolution imaging in conjunction with the analysis.

Most recently, a detector has been developed for the ORION helium ion microscope (Fig. 1) for measuring the energy of backscattered helium atoms in the intermediate energy range of ~30 keV. The detector relies upon the creation of electron-hole pairs as the helium atoms pass into a silicon active region, and the subsequent collection of the free charge. The total collected charge is an indication of the helium atom's incident energy. Some corrections are necessary to account for the other energy loss mechanisms, but these corrections are automatically performed through electronics and software to produce a useful measure of the backscattered helium atom's energy (Fig. 2). This energy, together with the limited angular acceptance of the detector, makes it possible to ascertain information about the elemental and structural composition of the sample. In addition, the backscatter *rate* provides further information to help distinguish different materials [5]. When equipped with this detector, the ORION helium ion microscope provides a unique combination of high resolution imaging and analysis. There are several applications for this new instrument – one of which is thin film analysis (Fig. 3).

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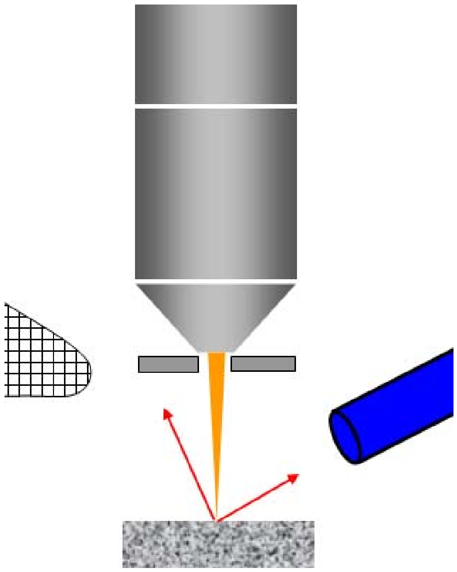

FIG. 1. The backscattered helium detector (blue cylinder) makes an angle of 65 degrees with the primary beam. It subtends a solid angle of 0.024 steradians. The annular MCP and ET grid are also shown.

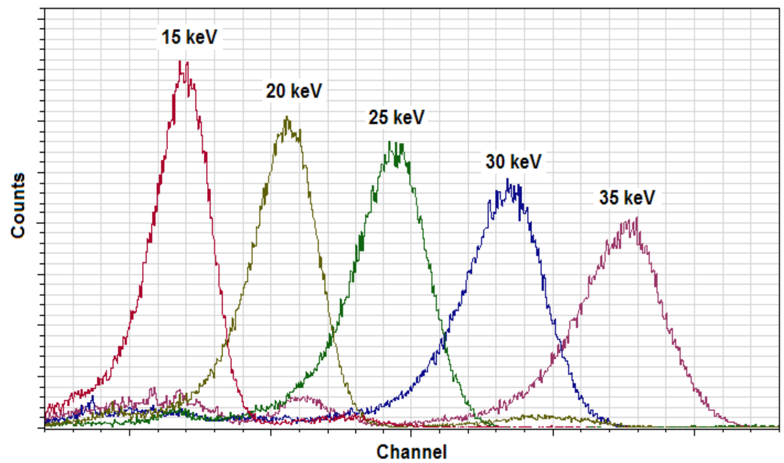

FIG. 2. A set of calibration spectra produced from a set of monoenergetic helium beams.

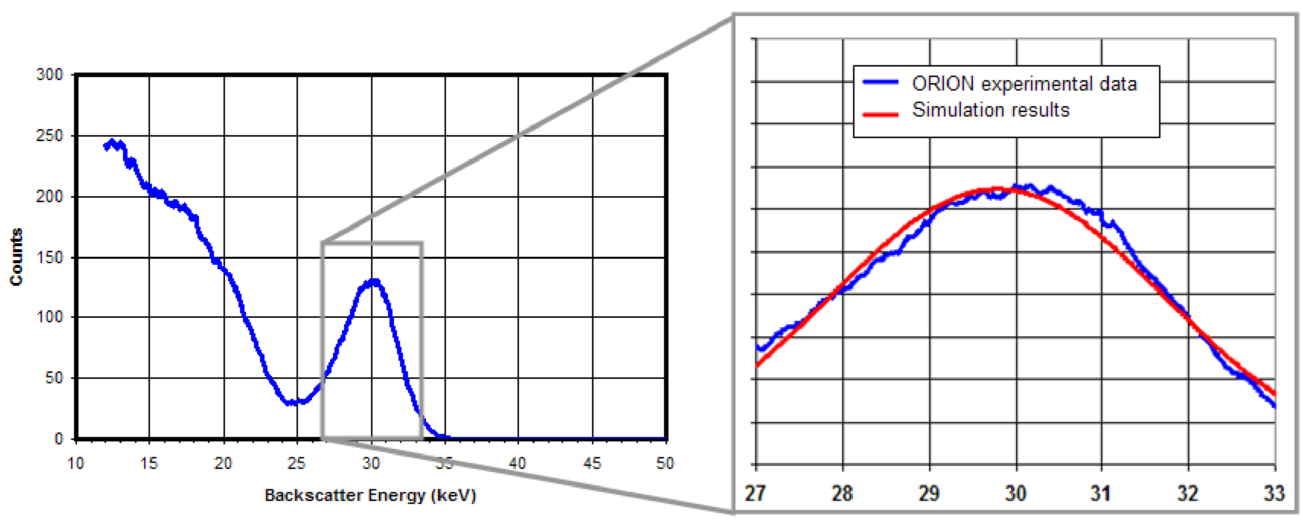

FIG. 3. A typical experimental energy spectrum from a thin film of ZrO_x on silicon. The inset shows that the experimental data (blue) is consistent with a simulation results (red, smooth curve) from a 12.1 nm film of ZrO_2. Samples provided courtesy of Dr. Steffen Teichert, Qimonda (Dresden, Germany).

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