806
doi:10.1017/S1431927612005880
Microsc. Microanal. 18 (Suppl 2), 2012

Exploiting Channeling in Helium Ion Microscopy

Gregor Hlawacek,[1] Vasilisa Veligura,[1] Stefan Lorbek,[2] Tijs F. Mocking,[1] Antony George,[3] Raoul van Gastel,[1] Harold J. W. Zandvliet,[1] and Bene Poelsema[1]

1. Physics of Interfaces and Nanomaterials, MESA+ Institute for Nanotechnology, University of Twente, PO Box 217, 7500AE Enschede, The Netherlands
2. Institute of Physics, Montanuniversitaet Leoben, Franz Josef Str. 18, 8700 Leoben, Austria
3. Inorganic Materials Science, MESA+ Institute for Nanotechnology, University of Twente, PO Box 217, 7500AE Enschede, The Netherlands

High resolution Secondary Electron (SE) images and Backscattered Helium (BsHe) images are the standard image types in Helium Ion Microscopy (HIM). The contrast ratio that can be achieved in both types of images is subject not only to the chemical composition but also depends on the crystal orientation. Channeling along low index directions affects SE as well as BSHe images.

In fig. 1 SE images of a polycrystalline Au{111} sample are presented. The polar angle of the incident beam was fixed at 35°. The change in grey level of several grains is plotted in fig. 2(a) for primary energies (PE) of 15 keV and 33.6 keV. The fact that for a low index channeling direction the SE yield drops by a factor of two demonstrates how important it is to properly align samples with respect to their crystallographic axis in HIM. Fig. 2(b) shows the opaque fraction in the projection of a modeled 12 layer Au slab for the same set of orientations as in fig. 2(a). The remarkable agreement between the two figures allows us to unambiguously identify the crystal orientation of the individual grains. In principle this angular dependence can be utilized to perform crystal orientation mapping comparable to electron back scatter diffraction.

In the second part we will discuss how channeling can be utilized to gain unexpected contrast in BsHe images on ultra thin surface layers. HIM already provides superior surface sensitivity in SE based images. Figure 3 presents BsHe and SE (inset) images of para-sexiphenyl (6P) islands grown on the native oxide of a Si{001} wafer [1,2]. While for normal beam incidence the island is clearly visible in both SE and BsHe images (left), the island is no longer discernable after tilting the sample by 10°. The fact that the island can be seen at all in a BsHe images cannot be explained by additional backscattering from the ad-layer due to the mass difference. SRIM calculations show that the additional back scattering from the lighter carbon ad-layer can be neglected. Moreover, tilting the sample should increase the surface sensitivity also in the BsHe image, but in contrast the island disappears. This can be understood if one accounts for the channeling of the He in the Si substrate. For normal beam incidence the sample is seen along a channeling direction. However, the carbon ad-layer locally blocks this channel and leads to an enhanced backscattering by dechanneling the ions. After tilting the sample sufficiently to lift the channeling condition for the underlying Si{001} the contrast vanishes. The presented work also underlines the importance of good vacuum conditions in HIM. We analyzed the projected opaque fraction of a Si crystal slab with and without a carbon ad-layer for several incident conditions. For normal incidence, the addition of only a single carbon ad-layer reduced the open area by 60%. As we have shown above, this changes the channeling conditions and subsequently will affect SE and BsHe yields. To avoid this effect the above presented experiments were performed in a unique ultra high vacuum HIM [3].

The described contrast mechanism for BsHe images extends the already high surface sensitivity in SE images to backscatter images. In addition, this effect will not depend on the mass of the element but on changes in the crystalline arrangement and will therefore also allow the identification of thin surface layers with similar composition but different crystallographic structure.

References

[1] G. Hlawacek et al., *Science* 321 (2008) 108-111.
[2] S. Lorbek et al., *Euro. Phys. J. Appl. Phys.* 55, 23902.
[3] R. van Gastel et al., *Microsc. Microanal.* 17 (S2) (2011), 928-929.
[4] This research is supported by the Dutch Technology Foundation STW, which is the applied science division of NWO, and the Technology Programme of the Ministry of Economic Affairs.

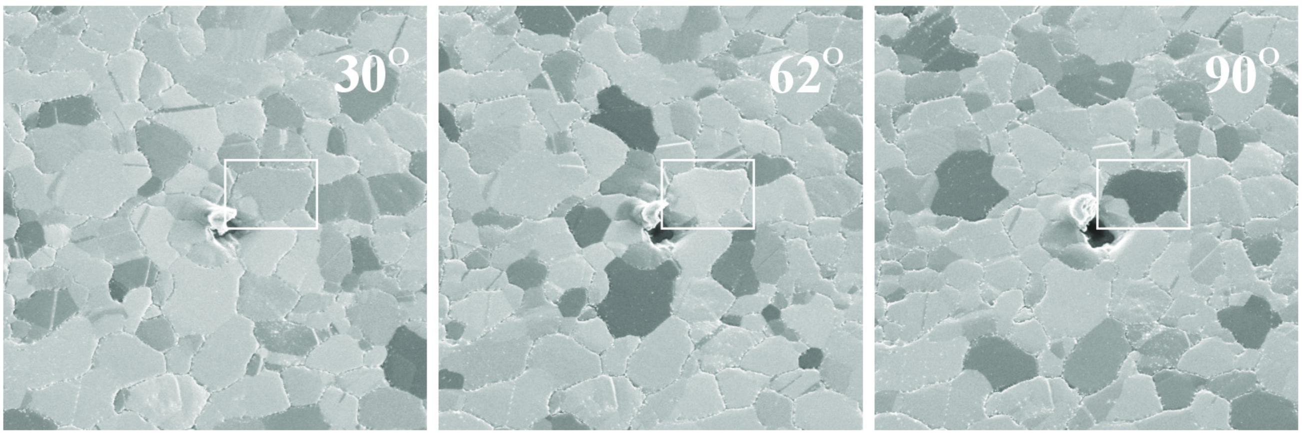
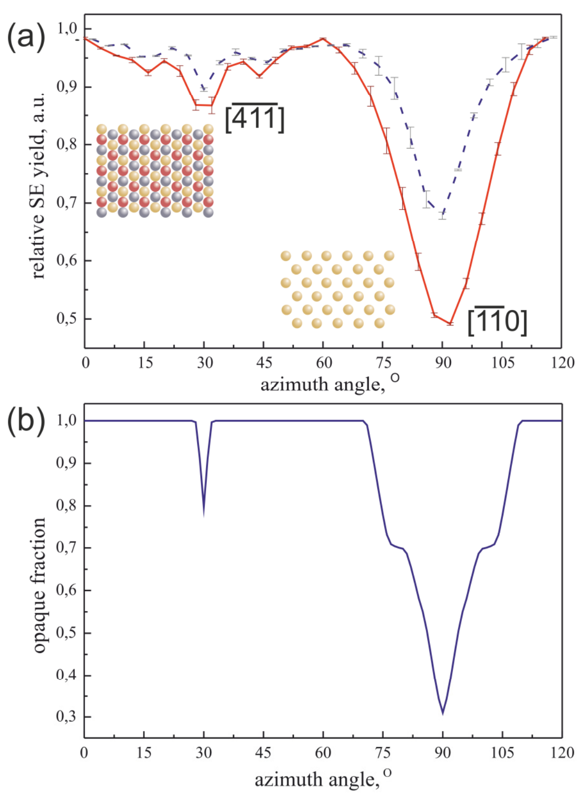


Fig. 1: HIM SE images of a hydrogen flame-annealed Au{111} film. Images have a field of view of 10 µm and were recorded with a PE of 15 keV. Azimuth angles presented are 30°, 62°, and 90°. The polar angle is fixed at 35°. The gray level of the marked grain changes from medium gray to bright and back to a dark gray level.



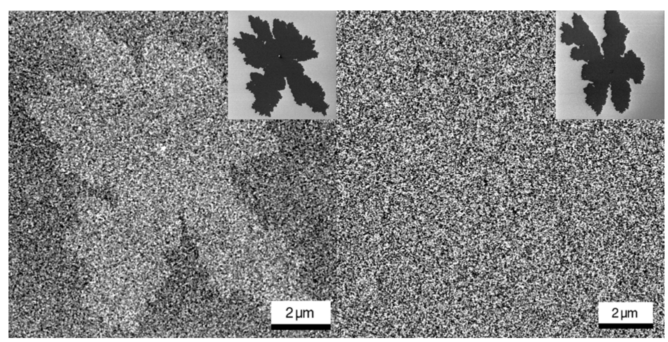


Fig 3: BsHe images of submonolayer 6P islands on SiO_2. Images recorded under identical conditions but with different tilt angles (left: 0°, right: 10°). Insets show the corresponding ET images.

Fig 2: Experimental obtained SE yield dependence on azimuth angle at a polar angle of 35°, PE: 15 kV (blue, dashed), 33.6 kV (red, solid). The insets are projected views of the crystal for the mentioned orientations. Atoms in the top, second and third layer are presented in gold, silver, and red, respectively. (b) Calculated dependence of opaque crystal fraction at 35°.