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ZEISS ORION NanoFab: New SIMS Spectrometer

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The ZEISS ORION NanoFab is well-established as a multi-ion beam (He, Ne, Ga) platform with many diverse applications. The helium beam is known to provide high resolution imaging with long depth of focus, surface sensitivity, and other novel contrast mechanisms [1]. The same instrument has demonstrated recent success in a range of nanofabrication techniques including lithography with resists [2], beam chemistry [3], precision sputtering [4], and ion beam induced functionalization [5]. The NanoFab is now available with an optional secondary ion mass spectrometer (SIMS) making this instrument the first multi-ion beam instrument for high resolution imaging, nanofabrication, and analysis.

The spectrometer is manufactured by Lion Nano-Systems, and is shown schematically in Figure 1. It consists of secondary ion (SI) extraction optics that can be retracted to enable full range of tilt and working distance for the sample. When inserted, the extraction optics introduces a transverse field to extract either positive or negative secondary ions with a transport efficiency estimated to be 40%. The ions are thereafter deflected to a region of high magnetic field which causes the ions to follow trajectories which depend on their mass. Individual detectors (channel electron multipliers) receive the ions and provide measured signal through pulse counting. The spectrometer allows for a mass resolution $M/\Delta M \sim 400$, and a full mass range from hydrogen to uranium.

A typical workflow might begin with the operator conducting a high resolution survey of the sample using the secondary electrons (SE) generated by the He beam in order to find the region of interest. With the feature of interest located, the helium beam is used to acquire a reference image with high resolution (~ 0.5 nm). Thereafter the SIMS extractor can be inserted and the column switched to Ne operation to take advantage of the higher sputter yields. The operator can perform a full sweep of the mass spectrum by ramping the magnetic field, or by moving one of the 3 detectors that are motorized. When the elements of interest are identified, the magnetic field and detector positions can be fixed, allowing thereafter for simultaneous acquisition of four mass filtered images. The mass filtered images provide high lateral resolution, capable of distinguishing line pairs with a pitch as small as 17.5 nm [6]. Multiple filtered images can be combined to produce color coded elemental maps, and further enhanced by their combination with the original SE high resolution image. Through the sputtering process, each successive image reveals deeper levels of information, allowing for 3D reconstruction and depth profiling.

Recent analytical results from the NanoFab with SIMS have yielded information-rich images in diverse fields including nanomedicine, metallurgy, photovoltaics [7][8], and advanced battery technology. In many cases, the results provide an image quality that could not be attained through any other instrument because of the high lateral resolution.

References:
[1] WL Rice et al., PLOS ONE **8(3)** (2013), p. e57051
[2] V Manichev et al., SPIE Advances in Patterning Materials and Processes **10586** (2018), p. 8.
[4] M Semple, E Baladi and AK Iyer. IEEE Selected Topics in Quantum Electronics (2019) (accepted for publication).
[5] L Kasaei et al., AIP Advances **8(7)** (2018), p.075020.
[6] B Lewis, F Khanom and J Notte, Microsc. Microanal. **24 (S1)** (2018), p. 850.
[7] P Gratia et al., Am. Chem. Soc. **138(49)** (2016), p. 15821.
[8] F Pérez-Willard, J. Braggin and TM Friedlmeier, Micrsc. Microanal. **24 (S1)** (2018), p. 848.

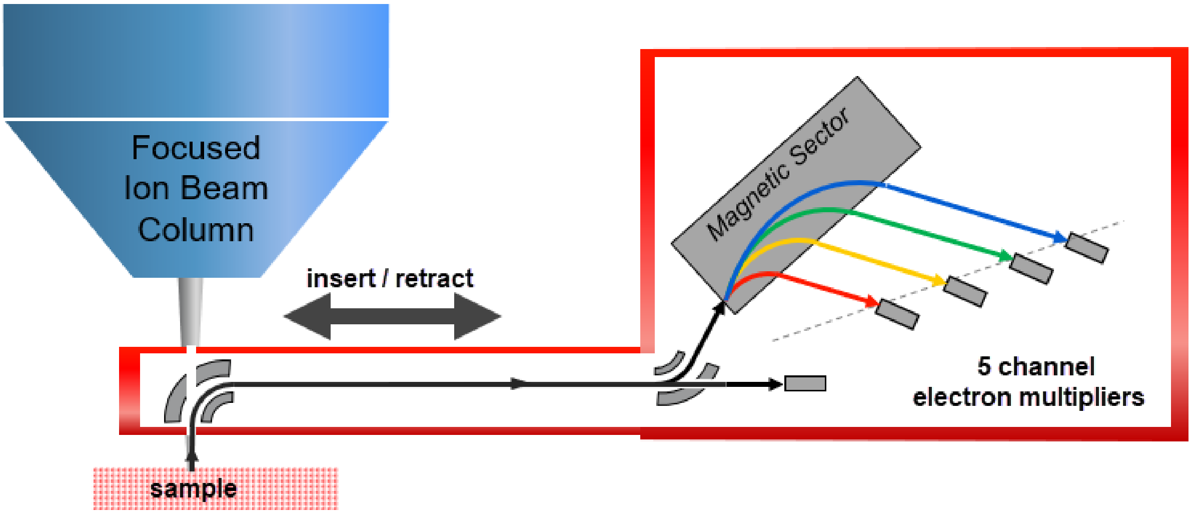

Figure 1. The spectrometer allows for mass identification with high lateral resolution (color).

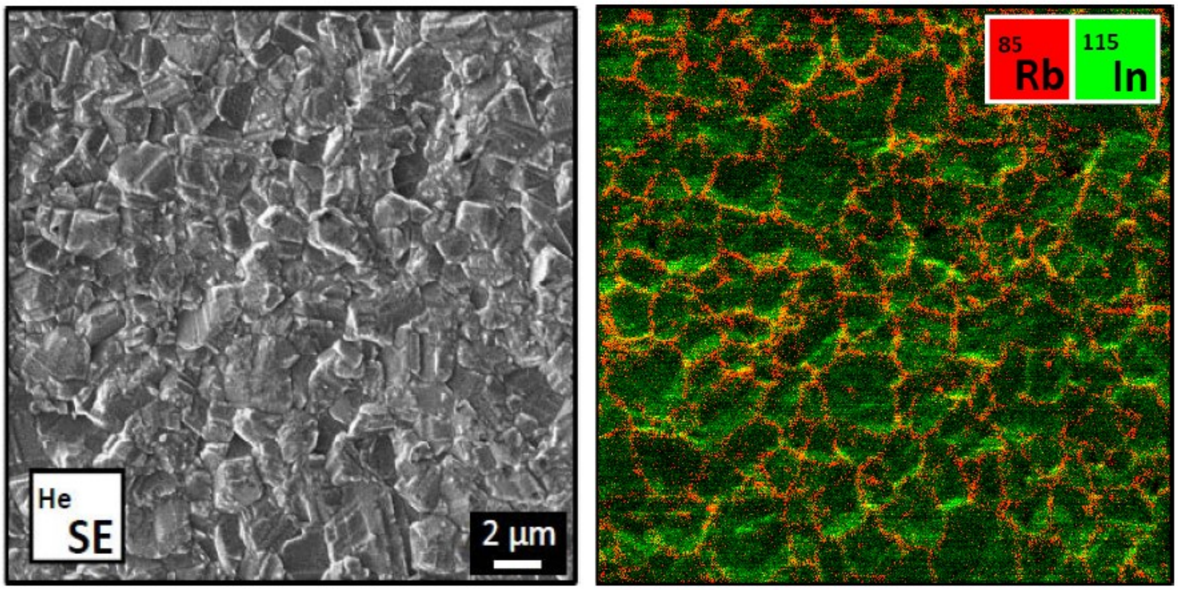

Figure 2. The same region of a CIGS absorber [8] imaged with the helium beam using secondary electrons (left) and imaged with neon beam with secondary ion detectors configured for rubidium and indium (right) (color). A clear segregation of rubidium towards the grain boundaries is plainly seen.