Tuesday Afternoon Poster Sessions

Helium Ion Microscopy Focus Topic
Room: East Exhibit Hall - Session HI-TuP

Aspects of Helium Ion Microscopy Poster Session

HI-TuP1 From HIM to NIM: The Prospects of a Neon Ion Microscope, ***F.H.M. Rahman***, *L.A. Stern, J.A. Notte*, Carl Zeiss NTS

From the time of its conception, the gas field ion source (GFIS) was operated with a variety of gas species - each considered for some particular virtue that depended on the particular application. However, practical issues such as vibration, cost, and stability prevented the commercial introduction of the GFIS for 50 years. The one gas species that was deemed to be most suitable was helium, and this was recently offered as a commercial product in the form of the ORION helium ion microscope in 2006. Now with several years of continued learning, the neon GFIS is being reconsidered in order to determine its suitability for the GFIS and the applications that it might enable.

The virtues of neon arise from its intermediate mass, one third the mass of gallium, and five times the mass of helium. While the helium probe offers minimal damage under normal imaging dosages (10^{15} ions/cm^2), the neon beam can sputter at much higher yield (typically 10 times the rate of helium – nearly half the yield of gallium). Compared to helium, the neon ions also penetrate less deeply, and produce many fewer sub-surface dislocations per surface sputtering event. For example, with a helium beam normally incident upon aluminum at 30 keV, there are about 1200 vacancies per sputtered atom according to SRIM. Under these same conditions, the neon beam produces just about 212 vacancies per sputtered atom, and these are located much closer to the surface. Also, the distribution of sputtering atoms is more localized to the incident beam location when neon is used. Compared to gallium, neon is expected to offer a much smaller probe size, and permit nanofabrication with much higher fidelity.

Experimental results will be presented to characterize the basic properties of the focused ion beam from our prototype neon GFIS system. Images will be provided to demonstrate our first cross-section milling and imaging characteristics.

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(See supplementary PDF online)

HI-TuP2 Helium Ion Microscope (HIM) Milling of Solid-State Nanopores for Single-Molecule Detection Devices, ***A.R. Hall***, University of North Carolina Greensboro, *J. Yang, D. Ferranti, L.A. Stern, J. Huang, J.A. Notte*, Carl Zeiss NTS

We report the formation of solid-state nanopores using the highly focused ion beam and lithographic capabilities of a scanning Helium Ion Microscope (HIM). We will discuss several aspects of the fabrication process, offering the advantage of high sample throughput along with fine control over nanopore dimensions. We will compare characteristics of the resultant devices with those made by the established technique of transmission electron microscope milling and demonstrate the utility of our nanopores for biomolecular analysis.

HI-TuP3 Imaging and Identification of Self Assembled Monolayers using HIM, ***G. Hlawacek***, *A. George, J.E. ten Elshof, R. van Gastel, H. Zandvliet, B. Poelsema*, University of Twente, The Netherlands

Helium Ion Microscopy (HIM) is a new and versatile tool for imaging and characterizing surfaces, buried interfaces, thin films and tackling many other problems in modern material science. HIM utilizes ionized Helium to scan the specimen surface. Secondary electrons created by the impinging ions allow to record morphology images with an unmatched lateral resolution of less than 0.35 nm. In addition, back-scattered ions carry the elemental information of the scattering partner – allowing for a elemental identification of the surface composition.

Here, we report on the visualization of thin self assembled monolayers (SAM) deposited on (001) silicon wafers, covered by a thin native oxide. In particular, SAMs formed by (3-Mercaptopropyl)trimethoxysilane (MPS) and Triethoxy-1H,1H,2H,2H-tridecaflouro-n-octylsilane (TDFOS) have been patterned into a rectangular stripe pattern using a two step gas-phase silanization process. The clever use of channeling into the underlying bulk (001) silicon, together with a work-function based evaluation of the secondary electron data allows a clear assignment of different sample areas to the different chemical species. This is possible for both the electron and the ion generated image. The importance of channeling to distinctly and visibly tag the different SAMs will be demonstrated.

HI-TuP4 Analysis of Metal Nanoparticles in Biological Tissues Specimens Using the Helium Ion Microscope, *V.S. Smentkowski*, ***L. Denault***, *D. Wark*, GE-GRC, *L. Scipioni, D. Ferranti*, Carl Zeiss SMT

The Helium Ion Microscope (HIM) is a newly introduced instrument that has a number of beneficial characteristics that are of importance for the analysis of biological/tissue samples, including: (1) the ability to perform high lateral resolution imaging, (2) high depth of field, (3) and the ability to analyze charging samples. In this poster, we summarize the first HIM analysis of spleen tissue samples that have been treated with a metal contrast agent. We show the advantages of HIM over techniques such as Scanning Electron Microscopy (SEM). The HIM analyis are complimented by surface analysis using Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS) in order to demonstrate that the contrast observed by HIM is indeed associated with the contrast agent.

HI-TuP5 Fabrication of Carbon Nanomembranes by Helium Ion Beam Lithography, ***X. Zhang***, *H. Vieker, A. Beyer, A. Gölzhäuser*, Bielefeld University, Germany

A helium-ion microscope can be used as beam writing tool on electron beam photoresists, such as hydrogen silsesquioxane (HSQ). It has been demonstrated to have a high resolution, a high sensitivity and a low proximity effect.

Here we report the fabrication of carbon nanomembranes from aromatic self-assembled monolayers (SAMs) with a helium ion beam as direct writing tool. Cross-linking of SAMs is achieved by exposure with helium ions which results in the formation of mechanically stable carbon nanomembranes. The required doses for cross-linking with helium ions are approximately one order of magnitude lower than with electrons. The cross-linked SAMs were transferred to either silicon substrates with an oxide layer for optical characterization or transmission electron microscopy (TEM) grids for preparing free-standing carbon nanomembranes.

With helium ion based cross-linking we fabricated patterned nanomembranes as well. Furthermore, the proximity effect and the sample damage on the nano-scale pattern is investigated and discussed.

HI-TuP6 Layer Thickness Homogeneity Determination via Rutherford Backscattering in Helium-Ion Microscopy, ***H. Vieker***, *K. Rott, A. Beyer, G. Reiss, A. Gölzhäuser*, University of Bielefeld, Germany

The recently developed helium-ion microscope allows remarkable surface resolution with the secondary-electron (SE) detector. Simultaneously, backscattered ions can be detected that allow imaging with a substantially higher elemental contrast. This Rutherford backscattered (RBS) ion contrast depends mainly on the elemental composition of the investigated sample surface. The escape depth of RBS ions is much larger than for secondary electrons. Thus whole layers with a wide range of thicknesses will contribute to a RBS ion image, whereas the SE image is far more surface sensitive, i.e. insensitive to buried parts under the sample surface.

In this contribution we examine RBS ion imaging as tool to characterize thickness variations of layered samples with well defined compositions. In a model example the homogeneity of a gold layer on a silicon substrate is investigated. The achievable spatial resolution for detecting buried inhomogeneities is analyzed. Furthermore we present examples with multiple layers.

HI-TuP7 Multi-Technique Approach to Study the Degradation Mechanism of used JLab Photocathode Samples, ***V. Shutthanandan***, *Z. Zhu, M.I. Nandasiri, S.V.N.T. Kuchibhatla, S. Thevuthasan, W.P. Hess*, Pacific Northwest National Laboratory, *C. Hernandez-Garcia*, Jefferson Lab

Degradation of the photocathode materials in accelerator-based photoinjectors represents a challenge for sustained beam delivery in proposed fourth generation light sources. The quantum yield in most existing photocathodes degrades over time leading to machine downtime for quantum yield replenishing and in some instances to photocathode replacement. Several photocathode degradation processes have been proposed including ion back bombardment, photochemistry of surface adsorbed species and irradiation-induced surface and bulk defect formation. At present, no consensus exists within the user community as to the mechanisms of photocathode damage. Better understanding of degradation mechanisms of existing photocathode materials could lead to improved emission properties and longer operating lifetime. Existing photocathode materials range from metallic (e.g. copper) to semiconducting (e.g. GaAs) with various structures, dopants, and surface preparations. Photocathode emission requirements include high electron yield and low thermal emittance at high repetition rate. The goal of this work is to thoroughly

characterize the used photocathode samples obtained from Jefferson lab using helium ion microscope (HIM), Rutherford backscattering spectrometry (RBS) in channeling and random directions, secondary ion mass spectrometry (SIMS), atom probe tomography(APT) and atomic force microscopy (AFM) to understand the degradation mechanism. Four different GaAs samples (two control including one as prepared and the other as annealed but not used, and two used to delivered 1000 and 7000 Coulombs) were analyzed using these techniques. HIM images obtained at the damaged spot from the 7000 C sample clearly show that the surface at this spot is severely damaged. In addition, some cracks are clearly visible on the surface. HIM images collected at the tilt angle of 20^{o} clearly show that these damage features are protruding above the surface of the photocathode samples at the center region of the spot. Stylus profilometer measurement on this spot reveals that the spot has peaks and valleys; the height of the main peak is around 7000 nm while the depth of the valleys ranges from 1000 to 3000 nm. It appears that the material in this area is melted. HIM images collected from all four samples clearly show that there is a systematic variation in the topography of the samples as a function of prolonged use of the photocathodes. The larger the usage time the smaller the structures are. Detailed analysis of these samples using RBS, SIMS together with HIM will be discussed.

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