Helium Ion Microscopy Focus Topic
Room: Hall D - Session HI-ThP

Aspects of Helium Ion Microscopy Poster Session

HI-ThP1 Fabrication of Single Atom Tip and Characteristics of Gas Field Ion Source at Room Temperature, ***In-Yong Park***, *B. Cho, C. Han, J. Kim, N.-K. Chung, S.J. Ahn*, KRISS, Korea

For a long time, scanning electron microscope (SEM) and transmission electron microscope (TEM) have been playing a significant role in research and industry, especially for high resolution imaging. However, both of them stand in need of sample preparation, such as coating with metal for non-conducting material and slicing for electron transmission, etc. Recently, helium ion microscope (HIM) shows that sub-nanometer imaging resolution could be possible regardless of conducting or non-conducting material without sample metal coating, including nanometer resolution patterning. HIM uses a gas field ion source (GFIS) which is different from tungsten filament, Schottky emitter and liquid metal ion source. In this work, we center around assessment of the characteristics and processes of GFIS in respect to temperature.

The needle like tip to which a high electric field is applied has a fundamental component in GFIS and much of the source physics of GFIS are very similar with field ion microscopy (FIM) [1]. When gases are introduced around the tip, polarized gases are attracted to tip and then ionized at an apex sites by transferring electron from gas to tip. If an ionization sites are confined to only a few atoms, then angular current density can be increased and adaptable to a charged particle microscope although the total current of ion beam is picoampere level. There are a lot of required conditions for generation of stable and high ion beam current. Among them, tip temperature which is related to stability, current density and energy spread is very important. Generally, in order to get an enough ion beam current, tip is cooled by refrigerant and maintained continuously. Supposing a source tip can be used for ion microscope at room temperature without cooling system, maintenance cost and price of apparatus will be reduced with simplified microscope. The aim of this study is to provide an overview of comparison of ion beam in cooled and uncooled tip. We observed the FIM of tungsten tip and fabricated the single atom tip through field assisted nitrogen etching [2]. Furthermore, to simplify the whole process, we did not anneal the tip for tip cleaning through resistive heating. We measured the total ion beam current generated from multi atom and single atom according to gas species, applying voltage, gas pressure and temperature. After that, we examined the potential to be an ion source, which generates ion beam at room temperature, for ion microscope by calculating an angular current density and stability.

[1] Müller, E.; Bahadur, K., Phys. Rev. 102, 624, 1956

[2] Rezeq, M., Pitters, J. and Wolkow, R, J Chem Phys. 124, 204716, 2006

HI-ThP2 Probing Structural Aspects of <10 nm-sized Young Soot, *M. Schenk*, University of Bielefeld, Germany, *S. Lieb*, University of Southern California, *H. Vieker, A. Beyer,* ***Armin Gölzhäuser***, University of Bielefeld, Germany, *H. Wang*, University of Southern California, *K. Kohse-Höinghaus*, University of Bielefeld, Germany

Because of its importance for climate, environment and health, detailed information on soot emission is needed. It is particularly important to understand how characteristic parameters, such as size, morphology, and chemical reactivity of soot particles depend upon the formation process. Small soot particles can be particularly dangerous since they can penetrate deeply into the respiratory tract and they may also be more reactive than more mature, larger particles [1]. Investigating the nature of <10 nm soot particles is thus of particular interest. We have studied the morphology of nascent soot probed from previously well-characterized burner-stabilized ethylene flames [2] with Helium-Ion Microscopy (HIM) . HIM allows unambiguous recognition of smaller nascent soot particles than those observed in previous transmission electron microscopy studies. With this technique, surface details are visible down to approximately 5 nm, and particles as small as 2 nm are detectable. The results demonstrate that nascent soot is structurally and chemically inhomogeneous, and even the smallest particles can have shapes that deviate from a sphere [3]. Structural details will be discussed.

[1] B. Frank, R. Schlögl, D.S. Su, Environ. Sci. Technol. **47**, 3026-3027, **2013**.

[2] A.D. Abid, N. Heinz, E.D. Tolmachoff, D.J. Phares, C.S. Campbell, H. Wang, Combust. Flame **154**, 775-788, **2008**.

[3] M. Schenk, S. Lieb, H .Vieker, A. Beyer, A. Gölzhäuser, H. Wang, K. Kohse-Höinghaus, ChemPhysChem **14**(14), 3248–3254, **2013**.

HI-ThP3 Fabrication of Carbon Nanotube Nanogap Electrodes by Helium Ion Sputtering for Molecular Contacts, *C. Thiele*, Karlsruhe Institute of Technology, Germany, *H. Vieker,* ***André Beyer***, Bielefeld University, Germany, *B.S. Flavel, F. Hennrich,* Karlsruhe Institute of Technology, Germany, *D.M. Torres, T.R. Eaton*, University of Basel, Switzerland, *M. Mayor, M.M. Kappes*, Karlsruhe Institute of Technology, Germany, *A. Gölzhäuser*, Bielefeld University, Germany, *H.V. Löhneysen, R. Krupke*, Karlsruhe Institute of Technology, Germany

We use helium ion beam lithography to sputter nanogaps of 2.8 ± 0.6 nm size into single metallic carbon nanotubes embedded in a device geometry (1). The high reproducibility of the gap size formation provides a reliable nanogap electrode testbed for contacting small organic molecules. To demonstrate the functionality of these nanogap electrodes, we integrate oligo(phenylene ethynylene) molecular rods, and measure resistance before and after gap formation and with and without contacted molecules.

(1) C. Thiele, H. Vieker, A. Beyer, B.S. Flavel, F, Hennrich, D.M. Torres, T.R. Eaton, M. Mayor, M.M. Kappes, A. Gölzhäuser, H.v. Löhneysen, R. Krupke: Fabrication of carbon nanotube nanogap electrodes by helium ion sputtering for molecular contacts, Appl. Phys. Lett., doi: 10.1063/1.4868097 (2014)

HI-ThP4 High Resolution UHV Helium Ion Microscopy of Work Function, Step Edges and Crystal Structure, ***Gregor Hlawacek***, Helmholtz-Zentrum Dresden - Rossendorf, Germany, *M. Jankowski, R. van Gastel, H. Wormeester, H.J.W. Zandvliet, B. Poelsema*, University of Twente, Netherlands

Helium Ion Microscopy---in particular under UHV conditions---is well know for it's high resolution imaging capabilities and the exceptional surface sensitivity. Here, we utilize both of these outstanding characteristics of this technology to visualize step edges, minute changes in composition and structural properties of a Ag/Pt alloy layer grown on Pt(111). A work function contrast of only a few ten's of meV allows to distinguish between areas of different Ag content in the alloy layer. As a result step edges on the Pt(111) crystal overgrown by the alloy layer become visible. Furthermore, the regular arrangement of FCC and HCP areas in the alloy layer could be revealed using fast Fourier image analysis and dechanneling image contrast. The measured spacing of 6 nm agrees well with the expected value. Low energy electron microscopy has been used to cross check the results and further analyze the alloy layer.

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HI-ThP6 Ion Beam Analysis in a Helium Ion Microscope, ***Nico Klingner***, *R. Heller, G. Hlawacek, S. Facsko, J. von Borany*, Helmholtz-Zentrum Dresden - Rossendorf, Germany

Helium ion microscopes (HIM) have become powerful imaging devices within the last decade. Their enormous lateral resolution of below 0.3 nm and the highest field of depth make them a unique tool in surface imaging. So far the possibilities to identify target materials (elements) are rather limited.

In the present contribution we will show concepts as well as preliminary studies on the capability, efficiency and the limits of applying (Rutherford) Backscattering Spectrometry (RBS) within a HIM device to image samples with target mass contrast and to analyze target compositions.

We will present different concepts of how to realize RBS in a HIM and point out mayor challenges and physical limitation.

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