Advanced Ion Microscopy and Ion Beam Nano-engineering Focus Topic
Room On Demand - Session HI-Invited On Demand

Advanced Ion Microscopy & Nano-Engineering Invited On Demand Session

HI-Invited On Demand-1 Nanoscale Vortex Pinning Structures in High-Temperature Superconductors Created in a Helium Ion Microscope*, **Wolfgang Lang**, B. Aichner,* University of Vienna, Austria*; M. Karrer, K. Wurster,* Universität Tübingen, Germany*; V. Misko,* Universiteit Antwerpen, Belgium*; K. Mletschnig,* University of Vienna, Austria*; M. Dosmailov,* Al-Farabi Kazakh National University, Kazakhstan*; J. Pedarnig,* University of Linz, Austria*; F. Nori,* RIKEN, Japan*; R. Kleiner, E. Goldobin, D. Koelle,* Universität Tübingen, Germany **INVITED**

The focused beam of a helium ion microscope is used to fabricate ultradense patterns of superconducting/insulating domains in thin films of the prototypical cuprate superconductor $YBa_2Cu_3O_{7-\delta}$ (YBCO) with unprecedented lateral resolution down to 40 nm. Simulations of the He^+ ion-target interactions [1] reveal 3-dimensional defect landscapes and allow one to determine the distribution of local critical temperatures in the material. The simulations anticipate that well-defined patterns of non-superconducting material in the superconducting matrix can be created with low blurring by focused 30 keV He^+ ion irradiation.

In such engineered defect patterns, the behavior of magnetic flux quanta, called Abrikosov vortices or fluxons, is investigated in view of emerging superconducting electronics, known as fluxonics. As an initial step along this route vortex commensurability effects are investigated that result from trapping fluxons at the engineered defects [2]. We report on the observation of novel commensurability effects in ultradense kagomé-like pinning patterns, where a competition between vortex pinning and the elastic energy of the distorted vortex lattice leads to unusual matching effects, as revealed by transport measurements and molecular-dynamic simulations [3]. Other intriguing observations in these ultradense superconducting patterns like vortex ratchet effects will be also discussed.

[1] K. L. Mletschnig and W. Lang, Microelectron. Eng. **215**, 110982 (2019).

[2]B. Aichner, K. L. Mletschnig, B. Müller, M. Karrer, M. Dosmailov, J. D. Pedarnig, R. Kleiner, D. Koelle, and W. Lang, Low Temp. Phys. **46**, 331 (2020).

[3]B. Aichner, B. Müller, M. Karrer, V. Misko, F. Limberger, K. L. Mletschnig, M. Dosmailov, J. D. Pedarnig, F. Nori, R. Kleiner, D. Koelle, and W. Lang, ACS Appl. Nanomater., **2**, 5108 (2019).

HI-Invited On Demand-7 Cluster Ion Beams: A New Tool for Characterization and Processing of Organic and Biological Materials*, **Jiro Matsuo**,* Quantum Science and Engineering Center, Kyoto University, Japan **INVITED**

Ion beams have been utilized for various applications, such as implantation, sputtering, etching and thin film formation for inorganic materials. However, it is quite difficult to apply ion beam technique for organic materials, because organic materials are easily decomposed with ion bombardments. This is due to the fact that bonding energy in organic molecule is much lower than a kinetic energy of ions. Recently, organic materials, such as functional-polymer, organic semiconductors and biological materials, are of interest in not only fundamental research but also many industrial applications. It has been demonstrated that large cluster ion beams have a great potential to sputter organic molecules without any residual damage on the surface, because cluster ion beams are equivalently low energy ion beams. Energy of cluster ion is shared with the constituent atoms in the cluster ion. For instance, when large Ar cluster ions with the cluster size of 1000 are accelerated with 10keV, each constituent atom has only 10eV/atom, which is comparable for binding energy of organic molecules. Therefore, cluster ion beams are now widely utilized for organic depth profile measurements in XPS or SIMS. More than 70% of those surface analysis system is delivered with GCIB source. It has been confirmed that no or very little damage is introduced on organic surfaces after large cluster ion bombardments. However, there is no report on molecular structure of sputtered species from organic materials. Sputtered molecules from PMMA were captured on Si wafers and measured with XPS technique. C 1s core level spectrum was almost identical to that of pristine PMMA. This measurement reveals that most of the carbon atoms have very similar chemical structures, but it is very difficult to measure molecular structures. We have also developed a finely focused large cluster ion beam (~1mm) for the primary ion beam for use in SIMS [1] and combined it with mass spectrometers of the quadrupole time-of-flight mass spectrometry (Q-TOF) type without pulsing primary ions. This mass spectrometer is equipped with MS/MS capability and allows to determine the structure of the secondary ion by using the collision-induced dissociation (CID) technique. This new system allows us to characterize 3D distribution of organic molecules.Fundamental phenomena of cluster ion collision with organic molecules will be discussed in conjunction with possible applications.

[1] J. Matsuo, S. Torii, K. Yamauchi, K. Wakamoto, M. Kusakari, S. Nakagawa, M. Fujii, T. Aoki, and T. Seki, *Appl. Phys. Express,* ***7*** (2014), 056602

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