DS 19: Ion and electron beam induced processes

Time: Wednesday 9:30–12:15 Location: H 2032

Invited Talk DS 19.1 Wed 9:30 H 2032

Ferromagnetic shape memory alloys: From ion-beam assisted synthesis to plasma-aided functionalization for biomedical applications — Ariyan Arabi-Hashemi[1,2], Uta Allenstein[1,3], Florian Szillat[1], Astrid Weidt[3], Mareike Zink[3], and •Stefan G. Mayr[1,2,3] — [1]Leibniz-Institut für Oberflächenmodifizierung e.V. (IOM), Leipzig — [2]Translationszentrum für regenerative Medizin — [3]Fakultät für Physik und Geowissenschaften, Universität Leipzig

Yielding magnetically switchable strains of several percent, ferromagnetic shape memory alloys bear enormous potential for contact-less actuators in biomedical applications. We report about recent progress in synthesis and characterization of freestanding Fe-Pd based ferromagnetic shape memory membranes. Energetic ion beams provide a powerful tool to precisely tune materials properties, including phase, the martensite-austenite transformation and magnetic behavior. Employing atomistic computer simulations, we unveil the underlying physics, which is dominated by changes in short range order and defect insertion. We also discuss latest plasma-aided functionalization strategies resulting in covalently-attached and crosslinked amino acids for mechanical coupling to biological cells and tissue. Density functional theory (DFT) calculation unravel the details of bonding, resulting in flexible, but highly durable polypeptide coatings.

[1] T. Edler, S.G. Mayr, Adv. Mater. 22, 4969 (2010).
[2] A. Arabi-Hashemi, S.G. Mayr, Phys. Rev. Lett. 109, 195704 (2012).
[3] M. Zink, F. Szillat, U. Allenstein, S. G. Mayr, Adv. Funct. Mat. 23, 1383 (2013).

Invited Talk DS 19.2 Wed 10:00 H 2032

Writing magnetic patterns using ion-beams — •Rantej Bali — Helmholtz-Zentrum Dresden-Rossendorf e.V, Bautzner Landstraße 400, 01328 Dresden.

In certain binary alloys, a large increase of the saturation magnetization can be triggered by subtle chemical disordering [1]. This phenomenon is linked to an increase in the number of nearest-neighbor magnetic atoms and local variations in the electronic band-structure due to the existence of disorder sites. An approach to induce disorder is to irradiate a chemically ordered precursor with energetic noble-gas ions; collision cascades formed by the ions knock atoms from their ordered sites and the concomitant vacancies are filled randomly *via* thermal diffusion of atoms. The ordered structure thereby undergoes a transition into a metastable solid solution. We consider the case of $Fe_{60}Al_{40}$ where the chemically ordered (B2) structure is paramagnetic; and the chemically disordered (A2) structure is ferromagnetic [2]. Such phase transitions can be deployed to pattern localized ferromagnetic regions, for instance, by irradiation through lithographed masks, or by direct writing using an ion-beam stylus. We demonstrate experimentally, the patterning of highly-resolved magnetic nanostructures embedded within topographically flat thin films. Materials in which the magnetic behavior can be tuned *via* ion-induced phase transitions may allow the fabrication of novel spin-transport and memory devices, such as lateral spin-valves, using existing patterning tools. [1] R. Bali *et al.*, Nano Lett. 14, 435 (2014). [2] J. Fassbender *et al.*, Phys. Rev. B 77, 174430 (2008).

DS 19.3 Wed 10:30 H 2032

Tailoring the magnetic easy axis of cobalt ferrite films by He implantation — •Andreas Herklotz[1], Antony Wong[1], Stefania Florina Rus[2], and Thomas Zac Ward[1] — [1]Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA — [2]National Institute for Research and Development in Electrochemistry and Condensed Matter, 300569 Timisoara, Romania

Heteroepitaxial strain engineering is an essential tool in the strongly correlated systems for investigating fundamental coupling effects and for more practical control of thin film properties. Recently, we have explored a new technique of strain control by the implantation of He into the film lattice. Here, we demonstrate the tuning of the magnetic anisotropy of $CoFe_2O_4$ (CFO) films through He doping by the use of a commercial ion gun. Compressively strained thin films of CFO are grown coherently on MgO substrates and show pronounced out-of-plane magnetic anisotropy. It is shown that He dosing of coherent films results in an expansion of the out-of-plane lattice parameter while the in-plane lattice stays epitaxial locked to the substrate. Simultaneously we observe a continuous rotation of the magnetic easy axis towards the film plane. The results demonstrate that He implantation is an elegant path to tune the magnetic anisotropy of oxide films and, more generally, desired characteristics of transition metal oxide thin films.
This work was supported by the U. S. Department of Energy, Office of Science, Basic Energy Sciences, Materials Science and Engineering Division.

DS 19.4 Wed 10:45 H 2032

Strong vortex matching effects in YBCO films with periodic modulations of the superconducting order parameter fabricated by masked ion irradiation — LT Haag[1], G Zechner[1], W Lang[1], •M Dosmailov[2], MA Bodea[2], and JD Pedarnig[2] — [1]University of Vienna, Faculty of Physics, Electronic Properties of Materials, Boltzmanngasse 5, A-1090 Wien, Austria — [2]Johannes-Kepler-University Linz, Institute of Applied Physics, Altenbergerstrasse 69, A-4040 Linz, Austria

We report on measurements of the magnetoresistance and of the critical current in thin films of the high-temperature superconductor YBa2Cu3O7-d (YBCO). A square array of regions with suppressed superconducting order parameter has been created in these films by introducing point defects via irradiation with He+ ions through a silicon stencil mask. In such a structure distinct peaks of the critical current can be observed at commensurate arrangements of magnetic flux quanta with the artificial defect lattice. Concurrently, the magnetoresistance shows pronounced minima. Both observations demonstrate that the strong intrinsic pinning in YBCO can be overcome by a periodic array of ion-damage columns with 300 nm spacing [1].

[1] L.T. Haag, M. Dosmailov et al, Physica C 503 (2014) 75-81.

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DS 19.5 Wed 11:00 H 2032

Modelling ion-induced pattern formation based on theories of erosion and mass redistribution using the crater function formalism — •Hans Hofsäss — II. Physikalisches Institut, Universität Göttingen, Göttingen, Germany

The Bradley-Harper (BH) and Carter-Vishnyakov (CV) theories with their recent extensions [1,2] are evaluated with regard to a quantitative prediction of ion-induced pattern formation on elemental and compound surfaces. The crater function formalism is applied and moments of the crater function were calculated using Monte Carlo simulations with the program SDTrimSP. The extensions to the linear theories give rise to additional curvature coefficients which have relevant impact on the formation of parallel ripples. The thickness dependence leads to a stabilizing contribution at intermediate angles. The curvature dependence of the crater function leads to a stabilizing contribution, except for larger angles where it becomes strongly destabilizing. With these extensions, the combination of BH and CV theory is able to quantitatively predict the angular regime for parallel ripple formation, the ripple wavelength and the initial growth rates. In particular, the extended theories are able to explain the absence of pattern formation in certain cases.

[1] M.P. Harrison,R.M. Bradley, Phys.Rev.B 89,245401(2014).
[2] H. Hofsäss, Appl. Phys. A 114 401 (2014).

DS 19.6 Wed 11:15 H 2032

Particle redeposition during ion-beam erosion can stabilize well-ordered nanostructures — •Christian Diddens[1] and Stefan J. Linz[2] — [1]Eindhoven University of Technology, The Netherlands — [2]Institut für Theoretische Physik, WWU Münster

We present a detailed analysis of a continuum model for the redeposition mechanism during the self-organized nanopatterning by ion-beam erosion. In particular, we investigate (i) the distribution of reattaching particles on the surface, (ii) an approximation of the latter as a function of the surface height and (iii) spatio-temporal evolutions of two-dimensional surfaces subject to combined erosion and redeposition. The most important finding is that redeposition can be an essential mechanism for the emergence of self-organized nanopatterns.

This stabilizing effect can be observed for a wide range of the entering parameters.

[1] C. Diddens and S. J. Linz, EPL, 104 (2013) 17010
[2] C. Diddens and S. J. Linz, Eur. Phys. J. B, 86 (2013) 397
[3] C. Diddens and S. J. Linz, (in preparation)

DS 19.7 Wed 11:30 H 2032

Interaction of Slow Highly Charged Ions with Ultrathin Membranes - Potential Sputtering, Energy Loss and Charge Exchange — •Richard A. Wilhelm[1], Elisabeth Gruber[2], Robert Ritter[2], René Heller[1], Stefan Facsko[1], and Friedrich Aumayr[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Wien, Wien, Austria

Slow highly charged ions (HCI) are known as an efficient tool for surface nano structuring of various insulating and semi-conducting surfaces. We show here that slow HCI can also be used to perforate a free-standing carbon nano membrane (CNM) with a thickness of only 1 nm. Round pores with sizes of up to 15 nm in diameter and corresponding sputter yields of up to a few thousand atoms are observed. Recent energy loss and charge exchange measurements on ions transmitted through a 1 nm thick CNM and free-standing Graphene reveal a strong dependence of the ion energy loss on charge exchange. Surprisingly, two distinct exit charge state distributions are observed, i.e. one part of the ions is almost neutralized and the other part remains in very high charge states after transmission. The ions potential and kinetic energy dependence on pore formation is discussed in terms of charge exchange and energy loss.

DS 19.8 Wed 11:45 H 2032

Epitaxial GaN films deposited on ion-beam structured Si(111) with SiN_x intermediate layer — •Annemarie Finzel, Jürgen W. Gerlach, Frank Frost, Renate Fechner, Marc Teichmann, Andriy Lotnyk, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e.V. (IOM Leipzig), Permoserstraße 15, D-04318 Leipzig, Germany

In this study, Si(111) substrates were structured by using a Kr ion beam in order to obtain nanometric ripple or terrace-like surface structures. After cleaning and oxide etching, the pristine as well as the ion-beam structured substrates were irradiated with hyperthermal nitrogen ions ($E_{kin} \leq 25$ eV) at elevated temperatures to create a thin SiN_x intermediate layer for preventing melt-back etching of the Si substrate surface by Ga. Immediately afterwards, thin GaN films were deposited on these pre-treated substrates by ion-beam assisted molecular-beam epitaxy (IBA-MBE). The characterization of the samples by (S)TEM and AFM shows that the 1-2 nm thin SiN_x intermediate layer is sufficient to protect the Si from melt-back etching. Although the layer is partially amorphous, it is possible to grow GaN films epitaxially on the SiN_x layer (FWHM of the c-plane XRD rocking curve: 2°). Furthermore, the findings reveal on the one hand a higher wettability of the ion-beam structured Si substrates, leading to more compact and dense films in comparison the non-structured ones. On the other hand, the GaN films deposited on the structured Si substrates exhibit a higher mosaicity (FWHM of the XRD rocking curves: 2.8-3.0°). The results will be discussed.

DS 19.9 Wed 12:00 H 2032

LMIS-Injector-Module including a beam formation unit for the generation of high mono- and polyatomic ion currents — •Philipp Laufer[1], Daniel Bock[1], Wolfgang Pilz[1], Lothar Bischoff[2], and Martin Tajmar[1] — [1]Technische Universität Dresden, 01062 Dresden — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden

A high current Liquid Metal Ion Source (LMIS) module including ion optics for beam formation is developed. This spin-off from aerospace research for ion propulsion units enables ion currents in the order of 100 μA [1]. A reservoir of more than 1 g propellant is used to guarantee long-term operation. The small module has a length and a diameter of 8 cm each. The ion optical components are designed and optimized by state-of-art simulation-tools to focus the highly divergent ion beam to a nearly parallel beam of about 2 mm diameter. About 10% of the total emitted current are cluster ions [2]. Together with a mass separating system the module will offer high polyatomic ion currents, which can be used to manufacture nanostructured or smooth surfaces on cm^2 area. Moreover, the module can be applied as a sputter tool for analysis of solid surfaces. As the majority of the sputtered particles are neutral the combination with an Electron Beam Ion Source (EBIS) [3] would enable to ionize these particles for mass analysis or to generate highly charged ions.

[1] M. Tajmar, et al., Ultramicroscopy 111 (2010)
[2] L. Bischoff, et al., Nucl. Instr. and Meth. B 272 (2012) 198
[3] M. Schmidt, et al., 12th Int. Symp. on EBIS a. Traps (EBIST'14)