KFM 24: Spectroscopy and Microscopy II with Positrons

Chair: Andreas Wagner (Helmholtz-Zentrum Dresden-Rossendorf)

Time: Thursday 9:30–12:20 Location: E 124

Invited Talk KFM 24.1 Thu 9:30 E 124

Discovering Ancient Secrets in Aluminum Alloys – A New Combination of Analytical Techniques and ab-initio Calculations — •Torsten E.M. Staab, Danny Petschke, Frank Lotter, and Elischa Bläss — LCTM, Universität Würzburg, Röntgenring 11, D-97070 Würzburg

Even though Aluminum alloy systems containing only two alloying elements seem to be just textbook example, there are still after decades of research unsolved problems in understanding the earliest stages of the formation of precipitates immediately after solution heat treatment and quenching. We tried to tackle these problems by a combination of different analytic method (DSC, XAFS, SAXS, PALS) combined with ab-initio calculations (SIESTA) of atomic configurations providing atomic positions for calculations of spectroscopic data and, thus, being able to directly compare our calculations to performed experiments.

For AlCu-alloys containing, on the one hand, Mg as a second alloying element we find that Mg-atoms are not catching quenched-in vacancies better than copper, as believe since long ago. However, the precipitation process seems to be triggered by large lattice distortions due to precipitation of Cu-platelets, where Mg atoms prefer lattice sites being under strain. On the other hand, we have been investigating the effect of trace elements in concentrations of 50 - 250ppm in 5N5 purity AlCu, where some of them (In, Sn) are known to bind quenched-in vacancies while other (Pb, Bi) – even larger in size – obviously do not have the same effect. The reason for this behavior is still under discussion.

KFM 24.2 Thu 10:00 E 124

Positron Annihilation Studies using a Superconducting Electron LINAC — •Andreas Wagner[1], Maik Butterling[1], Eric Hirschmann[1], Reinhard Krause-Rehberg[2], Maciej Oskar Liedke[1], and Kay Potzger[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden, Germany — [2]Martin-Luther-Universität Halle, Institut für Physik, 06099 Halle, Germany

The Helmholtz-Center at Dresden-Rossendorf operates several user beamlines for materials research using positron annihilation energy and lifetime spectroscopy. Two beamlines are being operated at a superconducting electron linear accelerator producing hard X-rays from electron-bremsstrahlung and in turn generating positrons from pair production. While one of the sources uses bremsstrahlung to directly generate positrons inside the sample of interest (named GiPS for Gamma-induced Positron Source), in the second source monoenergetic positrons (named MePS) with energies ranging from 500 eV to 25 keV are used for thin-film studies of porosity and defect studies. Examples of recent experimental results at all facilities will be presented. The MePS facility has partly been funded by the Federal Ministry of Education and Research (BMBF) with the grant PosiAnalyse (05K2013). The initial AIDA system was funded by the Impulse- und Networking fund of the Helmholtz-Association (FKZ VH-VI-442 Memriox). The AIDA facility was funded through the Helmholtz Energy Materials Characterization Platform.

KFM 24.3 Thu 10:20 E 124

An atomic investigation of the clustering on a Friction-Stir-Welding simulated Al-Cu-Li(-Mg) alloy by Positron Annihilation, SAXS, XAFS and DSC — •Danny Petschke, Frank Lotter, and Torsten Staab — University Würzburg, Dep. of Chemistry, Röntgenring 11, D-97070 Würzburg

Al-Cu-Li(-Mg) alloys find wide applications in aviation and aerospace technology due to the reduction of weight and their high strength at the same time. After rolling sheets of these alloys, a defined heat treatment leads to the formation of mainly T1-precipitates. These precipitates are highly efficient in blocking dislocations. When these sheets are joined by Friction-Stir-Welding (FSW), temperatures occuring in the Weld-Nugget (WN) are close to the material's solution treatment temperature. Hence, the T1-precipitates are completely dissolved in this region, which results in a significant hardness-drop. Only sub-nanometer sized GP(B)-zones and CuMg-clusters are formed directly after welding by diffusion processes not understood in detail, yet. We followed the precipitation directly after welding with Differential Scanning Calorimetry (DSC), giving information on formed precipitates, Small Angle X-ray Scattering (SAXS), giving information on size and volume fraction, Positron Annihilation Lifetime Spectroscopy (PALS), being sensitive to the formation and growth of precipitates, and, X-ray absorption spectroscopy (XAFS) as a fingerprint-method to identify the atomic structure by comparing the experimentally obtained spectra to simulations. Therefore, a Welding-Simulator was developed to reproduce the temperature in the welded material.

KFM 24.4 Thu 10:40 E 124

Thermal vacancies in highly diluted Al-In alloy — •Mohamed Elsayed[1,2] and Reinhard Krause-Rehberg[1] — [1]Institut für Physik, Martin-Luther Universität, Halle — [2]Physics Department, Minia University, Egypt

Positron annihilation lifetime spectroscopy (PALS) is applied to study the point defects generated in aluminum indium alloy upon quenching. Al alloy having 0.005-0.025 at % In is used in this study. The samples were homogenized for 2 h in the temperature range 320-620 °C, then rapidly quenched in ice water. They were immediately measured at room temperature (RT) by positron lifetime spectroscopy. The samples were isochronally annealed in the temperature range up to 327 °C in steps of 10 °C, they cooled down after each annealing step to RT and measured by PALS. It is found that the average positron lifetime increases to 240 ps with increasing quenching temperature up to 470 °C and it decreases slightly with further increase of the quenching temperature. A reference pure aluminum (99.9995) samples is quenched at different temperature to show the influence of the alloying element (In) on the vacancy formation. An average lifetime of 170, very close to the bulk value (158 ps), is obtained, indicating the role played by In on the vacancy formation. A defect-related lifetime of 247 ps is obtained in all quenched samples immediately after quenching. This lifetime corresponds mostly to vacancy-In complexes. The defect-related lifetime is found to decrease with increasing annealing temperature up to 127 °C reaching 225 ps, then it increases reaching 280 ps, corresponding to divacancy.

20 min. break

KFM 24.5 Thu 11:20 E 124

Curing processes in ultra low-k materials by positron annihilation spectroscopy — •Maciej Oskar Liedke[1], Nicole Köhler[2], Maik Butterling[1], Eric Hirschmann[1], Ahmed G. Attallah[3], Reinhard Krause-Rehberg[3], Stefan E. Schulz[2,4], and Andreas Wagner[1] — [1]Institut für Strahlenphysik, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany — [2]Zentrum für Mikrotechnologien, Tech. Univ. Chemnitz, Chemnitz, Germany — [3]Institut für Physik, Univ. Halle, Halle, Germany — [4]Fraunhofer ENAS, Chemnitz, Germany

The first results on in-situ investigations of pore formation in ultra low-k dielectrics during a curing process, i.e., a porogen removal by vacuum annealing will be presented. The main focus is to obtain insight into initial stages of pore networks formation up to their full development. The in-situ annealing and Doppler broadening positron annihilation spectroscopy measurements have been conducted on our Apparatus for In-situ Defect Analysis (AIDA) - the end-station of a slow positrons beamline at HZDR. In addition, positron lifetime spectroscopy has been utilized, where mono-energetic pulsed positron beam (MePS) serves as a probe to evaluate pore sizes, their concentration and distribution as a function of curing temperature and time. The MePS facility has partly been funded by the Federal Ministry of Education and Research (BMBF) with the grant PosiAnalyse (05K2013). The AIDA system was funded by the Impulse- und Networking fund of the Helmholtz-Association (FKZ VH-VI-442 Memriox) and through the Helmholtz Energy Materials Characterization Platform (03ET7015).

KFM 24.6 Thu 11:40 E 124

Investigation of the porous structure of oblique angle deposited thin films with tailored architectures using Positron Annihilation Spectroscopy — •Maik Butterling[1], Agustín González-Elipe[2], Maciej Oskar Liedke[1], Aurelio García-Valenzuela[2], Rafael Alvarez Molina[2], Alberto Palmero Acebedo[2], Jorge Gil-Rostra[2], Victor Rico Gavira[2], Eric Hirschmann[1], Reinhard Krause-Rehberg[3], and Andreas Wagner[1] — [1]Institut für Strahlenphysik, Helmholtz- Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Laboratory of Nanotechnology on Surfaces, Instituto de Ciencia de Materiales de Sevilla (CSIC-Universidad de Sevilla), Seville, Spain — [3]Insitut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

Oblique angle deposited (OAD) thin films offer many possibilities for tailoring their microstructure for specific applications, which are typically linked with the high fraction of void space and porosity available in these thin films (typically of 50% or more from the total volume of the films) and the possibility of tailoring their microstructure in the form of slanted, chiral, zig-zag or similar nanostructures. For applications, control and precise knowledge of the porous structures is essential which can be studied by means of Positron Annihilation Spectroscopy. We will present the first results for the investigation of three different nano-columnar systems which have been studied using the slow-positron source MePS at HZDR. The MePS facility has partly been funded by the Federal Ministry of Education and Research (BMBF) with the grant PosiAnalyse (05K2013).

KFM 24.7 Thu 12:00 E 124

Bound state resonances as a simplified model for the scaling of Compton profiles — •Jakob Bonart, Michael Sekania, and Liviu Chioncel — TP III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Germany

We recently showed that the shape of the Compton profiles of crystalline alkali metals can be fitted by a q-Gaussian distribution [M. Sekania et al., Physica A 489C, 18-27 (2018)], which implies a novel type of scaling of the Compton profiles. Here we discuss the correspondence between Compton scattering and the process in which a non-relativistic bound state absorbs a momentum. In our simplified model we derive the transition probability into the nth-bound level, demonstrate its scaling through the q-Gaussian scaling function, and connect the q-parameter to the shape of the confining potential. We propose that this mechanism causes the scaling of the Compton profiles of alkali metals.