MI 2: Untersuchung von kondensierter Materie mittels Positronen-Annihilation

Chair: R. Krause-Rehberg (Martin-Luther-Universität Halle-Wittenberg)

Time: Monday 10:00–13:00 Location: MER 02

Invited Talk MI 2.1 Mon 10:00 MER 02

Positronenstrahl-Mikroanalyse - Möglichkeiten und Herausforderungen — •Torsten E.M. Staab[1], Matz Haaks[2,3] und Karl Maier[2] — [1]LCTM, Universität Würzburg, Röntgenring 11, D-97070 Würzburg, Germany — [2]HISKP, Universität Bonn, Nußallee 14-16, D-53115 Bonn, Germany — [3]Aero-Laser GmbH, Unterfeldstr. 12, D-82467 Garmisch Partenkirchen

Während eine Elektronenstrahl-Mikrosonde die 2-dimensionale Abbildung der Verteilung von Elementen im Mikrometerbereich mittels deren charakteristischer Röntgenstrahlung ermöglicht, kann eine entsprechende 2-dimensionale Abbildung von leerstellenartigen Gitterbaufehlern durch eine Positronenstrahl-Mikrosonde erfolgen, da Positronen sensitiv auf Leerstellen und leerstellenartige Gitterbaufehler in Festkörpern sind. Dabei können nicht nur Leerstellen an sich sondern auch deren atomare Umgebung charakterisiert werden.

Neben verschiedenen Anwendungsmöglichkeiten der Positronenstrahl-Mikrosonde – eines modifizierten Rasterelektronenmikroskops – werden Beispiele zur Messung und zur Identifikation von Fehlstellen in Halbleitern und Aluminiumlegierungen mit Positronen gezeigt. Kombiniert mit anderen Methoden wie der Röntgenabsoptionsspektroskopie (XAFS) und der Röntgenkleinwinkelstreuung (SAXS), ergibt sich ein komplementäres Bild des Wechelspiels von Leerstellen und Legierungsatomen in Aluminiumlegierungen. Mit ab-initio Rechnungen ermittelte Atompositionen um Gitterbaufehler dienen dazu, Spektren zu simulieren, die dann direkt mit experimentellen Daten verglichen werden.

MI 2.2 Mon 10:45 MER 02

Development of a time- and position-resolving detector for 4D-AMOC — •Ulrich Ackermann, Werner Egger, Peter Sperr, Andreas Bergmaier, Christoph Greubel, and Günther Dollinger — Universität der Bundeswehr München, Institut für angewandte Physik und Messtechnik, Werner-Heisenberg-Weg 39, 85577 Neubiberg

The Pulsed Low Energy Positron System (PLEPS) at NEPOMUC at the Munich research reactor FRM2 is a powerful tool for depth resolved investigations of defects in solids via positron annihilation lifetime spectroscopy (PALS). Besides PALS two dimensional Age Momentum Correlation Measurements (2D-AMOC) are also possible where one measures the longitudinal momentum of the electron annihilating with the positron in addition with the positrons lifetime.

To measure the positrons lifetime together with the entire 3D-momentum of the electron annihilating with the positron (4D-AMOC) a pixelated Germanium detector in coincidence with a position sensitive scintillation detector will be used. The constraints for the scintillation detector are about 100 ps time resolution (FWHM) and circa 2 mm spatial resolution (FWHM) over an area of 12 cm^2 at gamma energies of 511 keV, respectively.

As scintillation detector we intend to use a MCP image intensifier detector coupled to a scintillator in addition with VME and NIM electronic modules and a MARaBOU/ROOT based data acquisition. First results of time resolution and position resolution with the scintillation detector setting will be presented.

MI 2.3 Mon 11:00 MER 02

Implementing the Munich Scanning Positron Microscope at NEPOMUC — •Marcel Dickmann[1], Christian Piochacz[2,3], Werner Egger[1], Gottfried Kögel[1], Peter Sperr[1], Christoph Hugenschmidt[2,3], and Günther Dollinger[1] — [1]Universität der Bundeswehr München, LRT2, D-85577 Neubiberg, Germany — [2]Technische Universität München, Physik Department E21, D-85748 Garching, Germany — [3]FRM2, Technische Universität München, D-85748 Garching, Germany

Positron annihilation lifetime spectroscopy is a very sensitive method to analyze non-destructively small open volume defects, e.g. vacancies, vacancy clusters, and dislocations. Defect-types and their concentrations can be determined. The Munich Scanning Positron Microscope (SPM) generates a focused, pulsed low-energy positron beam for positron lifetime measurements with a high lateral resolution ≥ 1 μm. By varying the beam energy, depth resolutions in the sub-μm range can be obtained, which makes 3D defect microscopy possible. With the SPM defect distributions close to crack surfaces have been successfully studied in pure copper and in the alloy Al 6013. The main limitation in these studies was the low count-rate obtainable with conventional laboratory positron sources, which leads to exceedingly long measurement times. Therefore, to increase the beam intensity, the SPM is transferred to the high intense positron source NEPOMUC at the FRM II research reactor in Munich. To match the stringent requirements on positron beam brilliance of the SPM, an interface, that increases the phase space density of the NEPOMUC beam, was built, and successfully tested.

MI 2.4 Mon 11:15 MER 02

Spin polarized 2D-ACAR study of the electronic structure of Nickel — •Hubert Ceeh[1], Josef-Andreas Weber[1], Michael Leitner[1], Christoph Hugenschmidt[1], Liviu Chioncel[2], Diana Benea[3], and Peter Böni[1] — [1]Technische Universität München, Physik Department, Lehrstuhl E21, James-Franck-Straße, D-85748 Garching, Germany — [2]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany — [3]Chemistry Department, University Munich, Butenandstraße 5-13, D-81377 München, Germany

2D-ACAR (Angular Correlation of Positron Annihilation Radiation) is a well known technique for the investigation of the electronic structure, i.e the Fermi surface of a material. For the properties of a metal the Fermi surface is a most important characteristic as it defines the boundary between occupied and unoccupied states in reciprocal space. In this contribution we give an overview on the measurement principle of spin-polarized 2D-ACAR. We then present our measurement of the momentum-density distributions of magnetic electrons in Nickel and compare these results with recent theoretical calculations based on the combined density functional and dynamical mean field theory. The overall structure of the experimental momentum densities are already reasonably reproduced without including dynamical electronic correlations, however we show that the slight quantitative discrepancies are reduced including the electronic correlations.

15 min. break

MI 2.5 Mon 11:45 MER 02

Positronen-Annihilations-Spektroskopie mit gepixelten Germaniumdetektoren zur 3D-Messung des Elektronenimpulses — •Benjamin Löwe[1], Markus Reiner[2], Werner Egger[1], Christoph Hugenschmidt[2] und Günther Dollinger[1] — [1]Universität der Bundeswehr, LRT2, Werner-Heisenberg-Weg 39, 85577 Neubiberg, Germany — [2]FRM II, Technische Universität München, Lichtenbergstraße 1, 85747 Garching, Germany

Aus dem dopplerverbreiterten Annihilationsspektrum von Positronen in Materie, kann man Aussagen über die chemische Umgebung des Annihilationsortes erhalten. Bei der Coincident Doppler Broadening Spectroscopy wird die Energie der Annihilationsstrahlung mit zwei Germaniumdetektoren in Koinzidenz gemessen. Dadurch erhält man eine Projektion des Elektronenimpulses. Um den vollen Elektronenimpuls zu messen ist es notwendig, zusätzlich zur Energie, die Winkelkorrelation der beiden Annihilationsquanten aufzunehmen.

Um dies zu erreichen haben wir ein Detektorsystem bestehend aus zwei 36-fach gepixelten Germaniumdetektoren sowie einer digitaler Datenaufnahme aufgebaut. An einem intensiven Positronenstrahl wurden bereits erste Testmessungen durchgeführt, die in diesem Beitrag vorgestellt werden.

MI 2.6 Mon 12:00 MER 02

Apparatus for In-situ Defect Analysis (AIDA) — •Maciej Oskar Liedke[1], Wolfgang Anwand[1], Kay Potzger[2], Alireza Heidarian[2], Rantej Bali[2], and Andreas Wagner[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Radiation Physics, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany

A unique high vacuum system combining material evaporation and ion beam modification with positron annihilation spectroscopy (PAS) has been developed and installed in the Helmholtz-Zentrum Dresden-

Rossendorf. The in-situ system is capable to perform Doppler broadening spectroscopy as well as resistometry (4 point probe). It is an end station of the Slow-Positron System of Rossendorf (SPONSOR) that provides a mono-energetic positron beam pre-accelerated in the range of 80 eV to 35 keV thus enabling sample depth profiling. The main focus of studies is the in-situ modification (during growth, ion irradiation, cooling/annealing) and the analysis of open volume defects and the chemical environment in thin films of, e.g., memristive oxides or metal alloys. First results on the FeAl ion irradiation/annealing driven magnetic phase transition between the paramagnetic and ferromagnetic state as a function of the open volume defects will be shown. The project is financed by the Impuls- und Vernetzungsfonds of the Helmholtz Association (code VH-VI-442).

MI 2.7 Mon 12:15 MER 02

Ion implantation induced damage in ZrO_2 probed by a slow positron beam — Wolfgang Anwand[1], Xin Ou[2], Maik Butterling[1], and •Andreas Wagner[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Radiation Physics, POB 51 01 19, 01314 Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, POB 51 01 19, 01314 Dresden, Germany

ZrO_2 in a cubic phase is generally known as YSZ (yttria-stabilized zirconia). YSZ is a promising material which exhibits excellent radiation resistance and chemical stability. It can be applied e.g. for the inter-matrix layer of fuel cells or for covering and storage of nuclear waste. The effect of irradiation on YSZ has already been intensively investigated via single ion beam implantation. Most of the experimental work was performed in order to simulate the radiation damage from alpha particles by He+ implantation, or to simulate the neutron radiation damage as well as the damage introduced from alpha recoils by implantation of heavy ions. Both I ions and He ions were implanted into YSZ samples. Single implantation of I ions as well as He ions, implantation of both types of ions at different sequence, and a simultaneous implantation with a dual beam were carried out in order to create varying defect profiles. Thereby it was intended to distinguish the various influences of the heavy and light ions on the defect profiles and to clarify a possible He retention or release after implantation. The implantation-induced damage was investigated by a mono-energetic slow positron beam.

MI 2.8 Mon 12:30 MER 02

Long-term ageing effects in reactor pressure vessel steels investigated by positron annihilation spectroscopy — •Maik Butterling[1], Wolfgang Anwand[1], Frank Bergner[2], Andreas Ulbricht[2], Andreas Wagner[1], and Arne Wagner[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Radiation Physics, POB 51 01 19, 01314 Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, POB 51 01 19, 01314 Dresden, Germany

Neutron irradiation of reactor pressure vessel steels leads to the formation of nano-sized defects which can deteriorate the material. An understanding of the microstructural evolution of the material is important for making reliable security assessments about possible future long-term operation of nuclear power plants.

So-called late-blooming phases [1-3] are formed after long-term irradiation and lead to considerable material ageing effects. Encouraging factors for the formation of these phases are a low Cu-content, moderate to high contents of Mn and Ni, low irradiation temperatures and different neutron fluxes.

Positron annihilation lifetime spectroscopy which is ideally suited for the detection and characterization of these irradiation-induced defects was applied for different selected materials which fulfill these conditions in order to investigate the occurrence and behavior of these phases.

[1] G.R. Odette, Mater. Res. Soc. Symp. Proc. 373 (1995) 137-148
[2] G.R. Odette and B.D. Wirth, J. Nucl. Mater. 251 (1997) 157
[3] R. Ngaymam-Happy et al., J. Nucl. Mater. 426 (2012) 198-207

MI 2.9 Mon 12:45 MER 02

MnSi Single Crystal Growth - Effects of the Outgasing of Mn Studied by Positron Annihilation Spectroscopy — •Markus Reiner[1,2], Wolfgang Anwand[3], Andreas Bauer[1], Maik Butterling[3], Thomas Gigl[1,2], Christian Pfleiderer[1], Andreas Wagner[3], and Christoph Hugenschmidt[1,2] — [1]Technische Univeristät München, Physik-Department, Lehrstuhl E21, James-Franck-Straße 1, 85748 Garching — [2]Technische Univeristät München, ZWE FRM-II, Lichtenbergstraße 1, 85748 Garching — [3]Helmholtz-Zentrum Dresden-Rossendorf, Kernphysik, Bautzner Landstraße 400, 01328 Dresden

The intermetallic B20 compound MnSi exhibits outstanding magnetic properties. Both the understanding of complex magnetic phenomena and the possible application as extremely efficient data storage material in future devices require the production of defect-free single crystalline MnSi.

For the present study, several MnSi single crystals have been grown from initial rods with a varying Mn excess in order to compensate the outgasing of Mn during crystal growth. The quality of the various crystals was examined by (coincident) Doppler broadening and positron lifetime spectroscopy. Wafers were investigated with the highly intense positron beam NEPOMUC at the FRM-II. In addition, the whole crystal rods were examined at the GIPS facility in the HZDR

The results clearly show that the open volume defects in MnSi can be efficiently reduced by inducing a slight Mn excess of several atomic percent in the initial rods used for single crystal growth.