Research Group for Spin-polarized Positron Beam

Group Leader: Atsuo Kawasuso

GroupActivities

Primary target of our research project is the establishment of a highly spin-polarized positron beam for the research on spin-electronic materials. We produce intense positron source (^{68}Ge-^{68}Ga) that yields much highly polarized positrons than the conventional ^{22}Na source through nuclear reactions. We perform the spin-polarized positron annihilation experiments. Employing previously developed reflection high-energy positron diffraction (RHEPD) and Positron microsope, we also promote the studies of surface low-dimensional materials and nuclear materials.

Spin-polarized electrons in Fe, Co, Ni and Gd detected by spin-polarized positron annihilation

The electron momentum distribution of a magnetic substance observed using spin-polarized positrons exhibits so-called field-reversal asymmetry as shown in Fig. 1 due to time-reversal symmetry breaking arising from excess electron spins [1]. The Doppler broadening of annihilation radiation (DBAR) spectra of Fe, Co, Ni, and Gd polycrystals measured using spin-polarized positrons from a ^{68}Ge-^{68}Ga source in magnetic fields exhibited clear asymmetry upon field reversal. The differential DBAR spectra between field-up and field-down conditions were reproduced in calculations considering polarization of positrons and electrons. The magnitudes of the field-reversal asymmetry for the Fe, Co, and Ni samples were approximately proportional to the effective magnetization. The magnetic field dependence of the DBAR spectrum for the Fe sample showed hysteresis that is similar to a magnetization curve. These results demonstrate that spin-polarized positron annihilation spectroscopy will be useful in studying magnetic properties of spin-electronic materials.

Atomic configuration of two-dimensional electron compound revealed by RHEPD

The adsorption of the noble and alkali metal atoms on the Si(111)-$\sqrt{3}\times\sqrt{3}$-Ag surface leads to the formation of $\sqrt{21}\times\sqrt{21}$ superstructures, accompanied by the drastic increase in the surface electrical conductivity. Recently, we found that the $\sqrt{21}\times\sqrt{21}$ superstructures are fabricated with different stoichiometry of the adsorbed binary metal atoms on the Si(111) surface. The atomic and electronic structures of the Au and Ag superstructure have been investigated using reflection high-energy positron diffraction (RHEPD), angle-resolved photoemission spectroscopy (ARPES), scanning tunnelling microscopy (STM), and semi-empirical theoretical approach [2]. As a result, we found that the Si(111)-$\sqrt{21}\times\sqrt{21}$ superstructure has a characteristic of electron compounds. We also found that the interaction energy among the adsorbates plays an important role in the formation of $\sqrt{21}\times\sqrt{21}$ superstructures.

This work was done in collaboration with Matsuda group of ISSP, University of Tokyo.

Stress-induced corrosion cracking observed by positron microscope

Stress corrosion cracking (SCC) is still an important issue in the low-carbon austenitic stainless steels developed as corrosion resistive materials for nuclear power plants. However, its mechanism has not yet been clarified. Recently, a hypothesis of the SCC crack propagation mediated by vacancy defects in a stress field near the crack tip is proposed. To investigate the vacancy formation during the SCC crack propagation, vacancy defects near the crack tip in stainless steel under tensile stress has been observed through *in-situ* positron microbeam measurements [3]. From the DBAR measurements of a stress-corrosion-cracked stainless steel, a clear increase of density of vacancy defects was observed over 200-400 μm areas from the SCC crack. From the comparison of the DBAR spectra obtained for the SCC sample and plastically deformed sample, the vacancy defects around the SCC crack were attributed to plastic deformation due to the stress concentration near the crack tip [4]. On the other hand, it is reported that vacancy defects in austenitic stainless steels migrate easily at a high temperature and move along the tensile stress. Crack progress by the SCC may occur preferentially in the crack tip where vacancy defects are accumulated

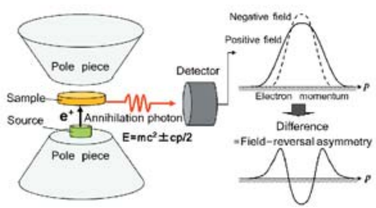

Fig. 1 Principle of spin-polarized positron annihilation spectroscopy (SP-PAS). Sample and source are placed in magnetic field. Longitudinally polarized positrons from the source are implanted into the magnetized sample and annihilation photons are detected by a Ge detector. Thus obtained DBAR spectrum reflects the electron momentum distribution. DBAR spectra for the field-up and field-down conditions are not identical due to the different spin statistics between positrons and electrons upon field reversal. This is called the field-reversal asymmetry. Field dependence of DBAR spectrum provides information on effective magnetization, electron spin-polarization and magnetization property of a magnetic substance. Considering the fact that positrons are trapped by vacancy defects, magnetisms induced by vacancy defects will be studied by SP-PAS method. By developing low-energy polarized positron beam, magnetic thin films and spin phenomena near surface will also be studied.

References

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Publication List

Publication List

Research Group for Condensed Matter Theory

Papers

1) Extremely long quasiparticle spin lifetimes in superconducting aluminium using MgO tunnel spin injectors, H. Yang, S. H. Yang, S. Takahashi, S. Maekawa, S.S.P. Parkin, *Nature Materials* **9**, 586-593 (2010).
2) Spin Seebeck insulator, K. Uchida, J. Xiao, H. Adachi, J. Ohe, S. Takahashi, J. Ieda, T. Ota, Y. Kajiwara, H. Umezawa, H. Kawai, G. E.W. Bauer, S. Maekawa and E. Saitoh, *Nature Materials* **9**, 894-897 (2010).
3) Quantum Renormalization of the Spin Hall Effect, B. Gu, J. Y. Gan, N. Bulut, T. Ziman, G. Y. Guo, N. Nagaosa, and S. Maekawa, *Phys. Rev. Lett* **105**, 086401-1-086401-4 (2010).
4) Surface-assisted spin Hall effect in Au films with Pt impurities, B. Gu, I. Sugai, T. Ziman, G. Y. Guo, N. Nagaosa, T. Seki, K. Takanashi, and S. Maekawa, *Phys. Rev. Lett.* **105**, 216401-1-216401-4 (2010).
5) Enhanced pairing correlations near oxygen dopants in cuprate superconductors, G. Khaliullin, M. Mori, T. Tohyama, and S. Maekawa, *Phys. Rev. Lett.* **105**, 257005-1-257005-4 (2010).
6) Observation of longitudinal spin-Seebeck effect in magnetic insulators, K. Uchida, H. Adachi, T. Ota, H. Nakayama, S. Maekawa and E. Saitoh, *Appl. Phys. Lett.* **97**, 172505-1-172505-3 (2010).
7) Gigantic enhancement of spin Seebeck effect by phonon drag, H. Adachi, K. Uchida, E. Saitoh, J. Ohe, S. Takahashi, and S. Maekawa, *Appl. Phys. Lett.* **97**, 252506-1-252506-3 (2010).
8) Dynamics of attractively interacting fermi atoms in one-dimensional optical lattices: Non-equilibrium simulations of fermion superfluidity, M. Okumura, H. Onishi, S. Yamada, and M. Machida, *Physica C* **470**, S949-S951 (2010).
9) Anomalous non-equilibrium electron transport in one-dimensional quantum nano wire at half-filling: time dependent density renormalization group study, M. Okumura, H. Onishi, S. Yamada, and M. Machida, *J. Phys.: Conf. Ser.* **248**, 012031-1-012031-7 (2010).
10) Effects of Mechanical Rotation on Spin Currents, M. Matsuo, J. Ieda, E. Saitoh, and S. Maekawa, *Phys. Rev. Lett.* **106**, 076601-1-076601-4 (2011).
11) Thermoelectric response in the incoherent transport region near Mott transition: the case study of $La_{1-x}Sr_xVO_3$, M. Uchida, K. Oishi, M. Matsuo, W. Koshibae, Y. Onose, M. Mori, J. Fujioka, S. Miyasaka, S. Maekawa, and Y. Tokura, *Phys. Rev. B* **83**, 165127-1-165127-5 (2011).
12) Numerical study on the spin Seebeck effect, J. Ohe, H. Adachi, S. Takahashi, and S. Maekawa, *Phys. Rev. B* **83**, 115118-1-115118-5 (2011).
13) Linear-response theory of spin Seebeck effect in ferromagnetic insulators, H. Adachi, J. Ohe, S. Takahashi, and S. Maekawa, *Phys. Rev. B* **83**, 094410-1-094410-6 (2011).
14) Giant spin Hall effect of Au films with Pt impurities: Surface-assisted skew scattering, B. Gu, T. Ziman, G. Y. Guo, N. Nagaosa, and S. Maekawa, *J. Appl. Phys.* **109**, 07C502-1-07C502-3 (2011).
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17) Microwave-induced supercurrent in a ferromagnetic Josephson junction, S. Hikino, M. Mori, S. Takahashi, and S. Maekawa, *Supercond. Sci. Technol.* **24**, 024008-1-024008-5 (2011).

Books & Reviews

1) From GMR to TMR, S. Maekawa, and J. Ieda, *BUTSURI* **65**, 324-330 (2010) (*in Japanese*).
2) New Interplay of Spin and Heat, H. Adachi, and S. Maekawa, *Magnetics Jpn* **5**, 256-263 (2010) (*in Japanese*).
3) New numerical approach for studying diluted magnetic semiconductors, J. Ohe, B. Gu, and S. Maekawa, *KOTAIBUTSURI* **45**, 269-278 (2010) (in Japanese).

Invited Talks

1) Possible mechanisms of enhanced pairing gap near apical and dopant oxygens in cuprate, M. Mori, *The 9th Asia Pacific Workshop on Materials Physics*, Hanoi, Vietnam (2010).
2) Spin-wave spin current in non-equilibrium systems, J. Ohe, *KIST Spintronics workshop*, Seoul, Korea (2010).
3) Spin motive force induced by the magnetic vortex core motion, J. Ohe, *International Conference of AUMS (ICAUMS2010)*, Jeju, Korea (2010).
4) Enhanced pairing correlation near oxygens in cuprate, M. Mori, *Super-PIRE/REIMEI workshop*, Knoxville, USA (2010).
5) Quantum transport in nano-structure of superconductor and ferromagnet, M. Mori, *ARW Workshop Hvar 2010*, Hvar, Croatia (2010).
6) Spin Current, Charge Current and their Interaction in Magnetic Nanostructures, S. Maekawa, *The 9th Asia Pacific Workshop on Materials Physics (APW2010)*, Hanoi, Vietnam (2010).
7) Spin-Wave Spin Current as a Transmission Tool of Electric Signal and Thermal Energy, S. Maekawa, *International Conference of AUMS (ICAUMS2010)*, Jeju, Korea (2010).
8) Spin-Wave Spin Current as a Transmission Tool of Electric Signal and Thermal Energy, S. Maekawa, *CRP Workshop on Oxide Electronics*, Singapore (2010).
9) Seebeck Effect, Spin Seebeck Effect and Spin-Electronics, S. Maekawa, *APW Workshop Hvar 2010*, Hvar, Croatia (2010).
10) Seebeck Effect, Spin Seebeck Effect and Spin-Electronics, S. Maekawa, *RIKEN Opening Symposium of QS2C Theory Forum*, Wako, Japan (2010).
11) Spin Current, Charge Current and their Interaction in Magnetic Nanostructures, S. Maekawa, *The 34th conference of The Magnetic Society of Japan, Tsukuba*, Japan (2010).
12) Spin-Wave Spin Current as a Transmission Tool of Electric Signal and Thermal Energy, S. Maekawa, *Spin Age 2010*, California, USA (2010).
13) Spin injection into a superconductor, S. Maekawa, *Shanghai Workshop on Spintronics and Low Dimensional Magnetism*, Shanghai, China (2010)
14) Spin Current, Charge Current and their Interaction in Magnetic Nanostructures, S. Maekawa, *KITPC 2010*, Beijing, China (2010).
15) Seebeck Effect, Spin Seebeck Effect and Spin-Electronics, S. Maekawa, *Workshop on High Performance Ceramic*, Hangzhou, China (2010).
16) Ferromagnetic Josephson Resonance, S. Maekawa, *SNS 2010*, Shanghai, China (2010).
17) Spin injection into a superconductor in a magnetic double tunnel junction, S. Maekawa, *ESF-NES Workshop 2010*, Salzburg, Austria (2010).
18) Materials Design of Magnetic Semiconductors -Quantum Monte Carlo Study-, S. Maekawa, *NASCES 2011*, Tokai, Japan (2011).

Research Group for Molecular Spintronics

Papers

1) Thermal Effect on Structure Organizations in Cobalt-Fullerene Nanocomposition, V. Lavrentiev, J. Vacik, H. Naramoto and S. Sakai, *J. Nanosci. & Nanotech.* **10**, 2624-2629 (2010).
2) RBS study of diffusion under strong centrifugal force in bimetallic Au/Cu thin films, T. Hao, M. Ono, S. Okayasu, S. Sakai, K. Narumi, Y. Hiraiwa, H. Naramoto and Y. Maeda, *Nucl. Instr. and Meth. in Phys. Res. B* **268**, 1867-1870 (2010).
3) Composition dependence of magnetic and magnetotransport properties in C_{60}-Co granular thin films, I. Sugai, S. Sakai, Y. Matsumoto, H. Naramoto, S. Mitani, K. Takanashi, and Y. Maeda, *J. Appl. Phys.* **108**, 063920-1-6 (2010).
4) Effect of ion irradiation on structure and thermal evolution of the Ni-C_{60} hybrid systems, J. Vacik, V. Lavrentiev, V. Vorlicek, L. Bacakova, and K. Narumi, *Nucl. Instr. and Meth. in Phys. Res. B* **268**, 1976-1979 (2010).
5) Observation of intermolecular N-I interaction during the growth of a 4-cyano-4'-iodobiphenyl molecular crystal on GeS(001), R. Sumii, M. Sakamaki, Y. Matsumoto, K. Amemiya, K. Kanai, and K. Seki, *Surf. Sci.* **604**, 1100-1104 (2010).
6) Interface Properties of Metal/Graphene Heterostructures Studied by Micro-Raman Spectroscopy, S. Entani, S. Sakai, Y. Matsumoto, H. Naramoto, T. Hao, and Y. Maeda, *J. Phys. Chem. C* **114**, 20042-20048 (2010).
7) Comparison of secondary ion emission yields for poly-tyrosine between cluster and heavy ion impacts, K. Hirata, Y. Saitoh, A. Chiba, K. Yamada, Y. Takahashi, and K. Narumi, *Nucl. Instr. and Meth. in Phys. Res. B* **268**, 2930-2932 (2010).
8) Atomic Structure and Energetic Stability of Complex Chiral Silicon Nanowires, P. V. Avramov, S. Minami, S. Irle, L. A. Chernozatonskii, and K. Morokuma, *J. Phys. Chem. C* **114**, 14692-14696 (2010).
9) Theoretical Study of Atomic Structure and Elastic Properties of Branched Silicon Nanowires, P. B. Sorokin, A. G. Kvashnin, D. G. Kvashnin, J. A. Filicheva, P. V. Avramov, and A. S. Fedorov, *ACS Nano* **4**, 2784-2790 (2010).
10) Theoretical Study of Elastic Properties of SiC Nanowires of Different Shapes, P. B. Sorokin, D. G. Kvashnin, A. G. Kvashnin, P. V. Avramov, and L. A. Chernozatonskii, *J. Nanosci. & Nanotech.* **10**, 4992-4997 (2010).
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12) Determination of silicon vacancy in ion-beam synthesized β-$FeSi_2$, Y. Maeda, T. Ichikawa, T. Jonishi, and K. Narumi, *Physics Procedia* **11**, 83-86 (2011).
13) Size-derived effects in electronic and elastic properties of diamanes, L. A. Chernozatonskii, P. B. Sorokin, A. A. Kuzubov, B. P. Sorokin, A. G. Kvashnin, D. G. Kvashnin, P. V. Avramov, and B. I. Yakobson, *J. Phys. Chem. C* **115**, 132-136 (2011).

Books & Reviews

1) The elastic properties of branched silicon nanowires: the theoretical study, P. B. Sorokin, A. G. Kvashnin, D. G. Kvashnin, P. V. Avramov, and L. A. Chernozatonskii, *Handbook of Chemistry, Biochemistry and Biology*: *New Frontiers*, 331-336, Nova Publishers (2010).
2) The study of the atomic structure and elastic properties of the silicon carbide nanowires, P. B. Sorokin, A. G. Kvashnin, D. G. Kvashnin, P. V. Avramov, and L. A. Chernozatonskii, *Handbook of Chemistry, Biochemistry and Biology: New Frontiers*, 325-330, Nova Publishers (2010).

Invited Talks

1) Spin polarization of organic molecules on magnetic surfaces probed by a metastable helium beam, Y. Yamauchi, *18th International Workshop on Inelastic Ion-Surface Collisions*, Gatlinburg, USA (2010).
2) Spintronic application and structure design of molecules and nanocarbons by quantum-beams, S. Sakai, *5th Takasaki Advanced Radiation Research Symposium*, Takasaki, Japan (2010).