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Positrons in surface physics ☆

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Abstract

Within the last decade powerful methods have been developed to study surfaces using bright low-energy positron beams. These novel analysis tools exploit the unique properties of positron interaction with surfaces, which comprise the absence of exchange interaction, repulsive crystal potential and positron trapping in delocalized surface states at low energies. By applying reflection high-energy positron diffraction (RHEPD) one can benefit from the phenomenon of total reflection below a critical angle that is not present in electron surface diffraction. Therefore, RHEPD allows the determination of the atom positions of (reconstructed) surfaces with outstanding accuracy. The main advantages of positron annihilation induced Auger-electron spectroscopy (PAES) are the missing secondary electron background in the energy region of Auger-transitions and its topmost layer sensitivity for elemental analysis. In order to enable the investigation of the electron polarization at surfaces low-energy spin-polarized positrons are used to probe the outermost electrons of the surface. Furthermore, in fundamental research the preparation of well defined surfaces tailored for the production of bound leptonic systems plays an outstanding role. In this report, it is envisaged to cover both the fundamental aspects of positron surface interaction and the present status of surface studies using modern positron beam techniques.

Keywords: Polarized positron beams; Positron diffraction; Positron annihilation induced Auger-electron spectroscopy; Positronium; Reconstructed surfaces; Adatoms

Contents

Acronyms: ACAR, Angular correlation of annihilation radiation; AES, Auger-electron spectroscopy; AMOC, Age-MOmentum Correlation; APECS, Auger photo-electron coincidence spectroscopy; ARPES, Angle-resolved photo emission spectroscopy; BEC, Bose–Einstein condensate; CDBS, Coincident Doppler-broadening spectroscopy; CISP, Current-induced spin polarization; CMM, Corrugated mirror model; cps, counts per second; DBS, Doppler-broadening spectroscopy; DFT, Density functional theory; EAES, Electron induced Auger-electron spectroscopy; FWHM, Full width at half maximum; IMFP, Inelastic mean free path; LEED, Low-energy electron diffraction; LEPD, Low-energy positron diffraction; MCP, Micro-channel plate; ML, MonoLayer; NEPOMUC, NEutron induced POsitron source MUniCh; PALS, Positron annihilation lifetime spectroscopy; PAS, Positron annihilation spectroscopy; PAES, Positron annihilation induced Auger-electron spectroscopy; Ps, Positronium (o-Ps and p-Ps: ortho-Ps and para-Ps); RHEED, Reflection high-energy electron diffraction; RHEPD, Reflection high-energy positron diffraction; SNR, Signal-to-noise ratio; SOC, Spin–orbit coupling; SPM, Scanning positron microscope; STM, Scanning tunneling microscope; STS, Scanning tunneling spectroscopy; SXRD, Surface X-ray diffraction; TEM, Transmission electron microscope; TOF, Time of flight; TRHEPD, Total reflection high-energy positron diffraction; UHV, Ultra high vacuum; UPS, Ultraviolet induced photo-electron spectroscopy; XAES, X-ray induced Auger-electron spectroscopy; XPS, X-ray induced photo-electron spectroscopy; XRD, X-ray diffraction

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1. Introduction

In surface science the structure and elemental composition ideally of the topmost atomic layer of a solid and all kinds of phenomena related to the surface are subject of most research activities. For this a zoo of well-known standard analysis tools based on spectroscopic, microscopic, scattering and diffraction methods are commonly applied.