Progress in Surface Science xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Progress in Surface Science

journal homepage: www.elsevier.com/locate/progsurf

Review

The influence of electron confinement, quantum size effects, and film morphology on the dispersion and the damping of plasmonic modes in Ag and Au thin films

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ARTICLE INFO

Commissioning Editor: P.M. Echenique

Keywords:
Surface plasmons
Surface plasmon lifetime
Metallic thin films
Electron energy loss spectroscopy
Dynamic screening
Acoustic surface plasmon

ABSTRACT

Plasmons are collective longitudinal modes of charge fluctuation in metal samples excited by an external electric field. Surface plasmons (SPs) are waves that propagate along the surface of a conductor. SPs find applications in magneto-optic data storage, optics, microscopy, and catalysis.

The investigation of SPs in silver and gold is relevant as these materials are extensively used in plasmonics. The theoretical approach for calculating plasmon modes in noble metals is complicated by the existence of localized d electrons near the Fermi level. Nevertheless, recent calculations based on linear response theory and time-dependent local density approximation adequately describe the dispersion and damping of SPs in noble metals.

Abbreviations: 2DEG, two-dimensional electron gas; 3DEG, three-dimensional electron gas; AERPY, angle- and energy-resolved photo-yield; AES, Auger electron spectroscopy; ARPES, angle-resolved photoemission spectroscopy; ASP, acoustic surface plasmon; BP, bulk plasmon; CID, chemical interface damping; DFT, density functional theory; e–h, electron–hole; FWHM, full-width at half maximum; HREELS, high-resolution electron energy loss spectroscopy; ISP, interband surface plasmon; LEED, low-energy electron diffraction; LEEM, low-energy electron microscopy; ML, monolayer; MP, multipole plasmon; QMD, quenched molecular dynamics; QWS, quantum well states; RPA, random phase approximation; RT, room temperature; SERS, surface-enhanced Raman spectroscopy; SP, surface plasmon; STM, scanning tunnelling microscopy; TDLDA, time-dependent local density approximation; TOF-ICISS, time-of-flight impact-collision ion scattering spectroscopy; XPS, X-ray photoemission spectroscopy.

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http://dx.doi.org/10.1016/j.progsurf.2014.12.002

Please cite this article in press as: A. Politano, G. Chiarello, The influence of electron confinement, quantum size effects, and film morphology on the dispersion and the damping of plasmonic modes in Ag and Au thin films, Prog. Surf. Sci (2015), http://dx.doi.org/10.1016/j.progsurf.2014.12.002

Furthermore, in thin films the electronic response is influenced by electron quantum confinement. Confined electrons modify the dynamical screening processes at the film/substrate interface by introducing novel properties with potential applications. The presence of quantum well states in the Ag and Au overlayer affects both the dispersion relation of SP frequency and the damping processes of the SP.

Recent calculations indicate the emergence of acoustic surface plasmons (ASP) in Ag thin films exhibiting quantum well states. The slope of the dispersion of ASP decreases with film thickness.

High-resolution electron energy loss spectroscopy (HREELS) is the main experimental technique for investigating collective electronic excitations, with adequate resolution in both the energy and momentum domains to investigate surface modes.

Herein we review on recent progress of research on collective electronic excitations in Ag and Au films deposited on single-crystal substrates.

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