Mechanisms for plasmon excitation by slow ion impact on clean Al

Hannes Eder, Friedrich Aumayr, and Hannspeter Winter

Institut für Allgemeine Physik, Technische Universität Wien
Wiedner Hauptstrasse 8-10, A-1040 Wien, Austria
E-mail: winter@iap.tuwien.ac.at, Website: http://www.iap.tuwien.ac.at

Plasmon excitation for impact of slow ions ($v_i \ll 1$ au) on a clean metal surface has recently been demonstrated [1, 2, 3] by a small contribution in resulting electron spectra at an electron energy of $E_p - W_\phi$ (E_p plasmon energy, W_ϕ surface work function). For clean Al ($W_\phi = 4.2$ eV), one-electron decay of a bulk plasmon ($E_p = 15.3$ eV) contributes at about 11 eV. Such slow-ion induced plasmons may be excited either "directly" in competition with potential (Auger-type) electron emission (PE) if the potential projectile energy exceeds E_p, or "indirectly" due to fast electrons resulting from PE or kinetic emission (KE). We attempt to determine the relative importance of both excitation processes from electron spectra measured for impact of slow H^+, He^+, Ne^+, Ne^{2+} and Ar^+ (1 – 5 keV) on atomically clean polycrystalline Al. The target is rotatable with respect to the incident ion direction inside a cylindrical shield, around which a 90° electron spectrometer can be turned for selection of different electron emission angles. Total electron yields have been obtained from target currents measured at different target biasing. The impact energy and the angle of incidence ψ of the projectile ions, and the electron emission angle α have been systematically varied. The magnetic background field impeding a correct measurement of the low-energy part of the electron spectra has been suppressed by μ–metal shielding of the target region and the electron spectrometer. The residual (also time-varying) field has been further suppressed by three Helmholtz coil pairs which are feed-back controlled by magnetic field sensors in all three spatial directions. Projectile ions (typical ion current on target 10 – 200 nA) have been obtained from a 5 GHz ECR ion source.

Fig. 1 shows a set of electron spectra measured for impact of 7 keV Ne^+ at an angle of $\psi = 5°$ with respect to the target surface. With reference to this data, principal results of our study can be summarized as follows. For all projectile ions, with increasing angle α the maximum of the electron spectra shifts toward higher energy. This is ascribed to an accordingly smaller escape path of KE electrons, which is a consequence of the decreasing mean-free path of slow electrons in the target bulk with increasing electron energy. Near 11 eV the broad yet weak peak due to bulk plasmon decay can be observed which becomes slightly more prominent with larger α when a thicker target layer is probed. For impact of Ne^{2+} and He^+ we find a comparably strong bulk plasmon peak as for Ne^+, but there is clearly less important plasmon excitation for impact of H^+ and Ar^+. Electron emission from doubly excited Ne atoms [4] between 20 and 30 eV exhibits a clear Doppler shift with variation of α. For impact of He^+ a similar behaviour is found. Finally, there is Auger electron emission related to Al L-shell vacancy production at 63 eV. The peak is more pronounced for impact of Ar^+, but much weaker or practically absent for He^+ and H^+. As already mentioned in [2], these comparably fast Auger electrons can "indirectly" excite plasmons in the Al target, as demonstrated by weak electron loss peaks

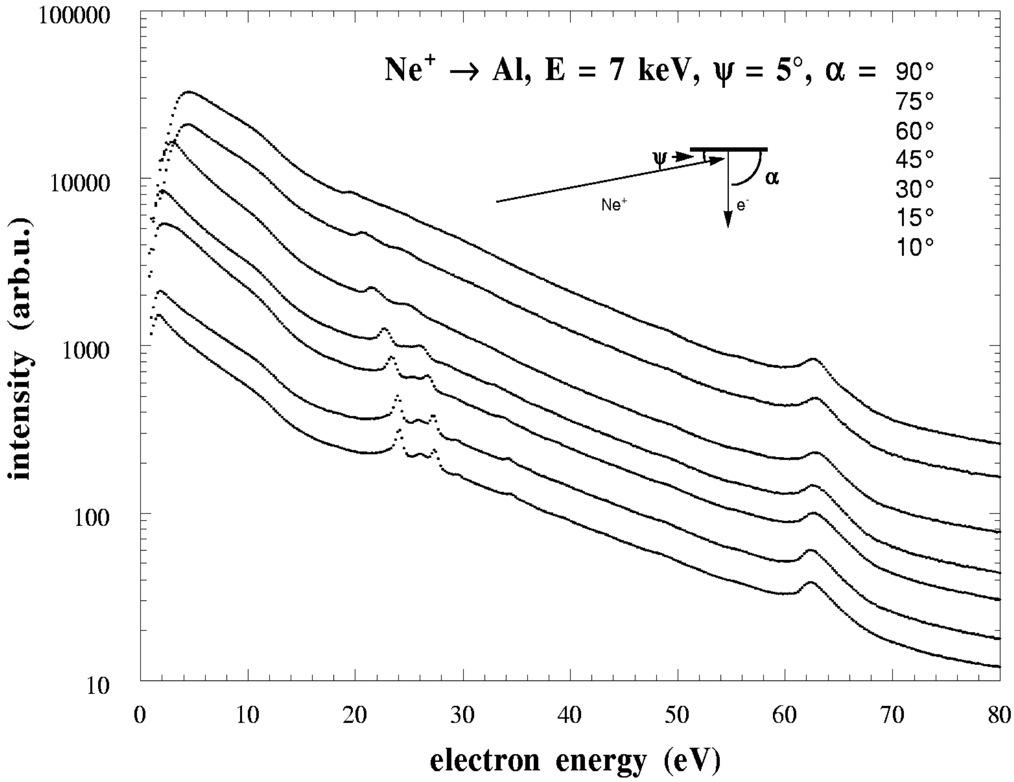

Figure 1: Electron energy spectra for impact of 7 keV Ne$^+$ (ψ = 5°) on atomically clean polycrystalline Al. The electron emission angle α was changed between 10° and 90° (see insert). Intensities of the different spectra have been arranged for better visibility.

at the correspondingly lower electron energy.

Our goal is to determine for each collision system the relative importance of "direct" and "indirect" plasmon excitation processes. So far, we have found no evidence for surface plasmon production [1, 2] but a definitive conclusion on this point is expected from similar studies with a monocrystalline Al target.

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