



Measurement of the surface excitation probability of medium energy electrons reflected from Si, Ni, Ge and Ag surfaces

Wolfgang S.M. Werner ^{a,*}, László Kövér ^b, Sándor Egri ^b,
József Tóth ^b, Desző Varga ^b

^a *Institut für Allgemeine Physik, Vienna University of Technology, Wiedner Hauptstraße 8–10, A 1040 Vienna, Austria*

^b *Institute of Nuclear Research of the Hungarian Academy of Sciences, P.O. Box 51, H 4001 Debrecen, Hungary*

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Abstract

Reflection electron energy loss spectra (REELS) are presented for medium energy (200 eV to 5 keV) electrons back-scattered from Si, Ni, Ge and Ag surfaces. Multiple bulk inelastic scattering is eliminated from the experimental spectra and the differential surface excitation probability is retrieved from the resulting spectra. The differential as well as the integral surface excitation probabilities are compared with available theoretical results and experimental data published earlier. A material parameter is derived from the measurements that describes the dependence of the average number of surface excitations experienced in a single surface crossing on the electron energy and direction of surface crossing. While the shape of the distribution of energy losses in a single surface excitation is in reasonable agreement with theory, the integral surface excitation probability, i.e. the number of surface excitations experienced by the probing electron during a single surface crossing, exhibits a significant scatter when comparing results from different sources.

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1. Introduction

Electron spectroscopic methods, such as XPS, AES, REELS and EPES are powerful tools of surface chemical analysis, capable for providing information on fine details of materials electronic structure as well as on the interactions leading to

* Corresponding author. Tel.: +4315880113462; fax: +4315880113499.

E-mail address: werner@iap.tuwien.ac.at (W.S.M. Werner).

excitation of photo- and Auger electrons and to their further scattering within the solid during transport towards the surface. This information, however, is embedded in the electron spectra and the complete separation of various contributions attributable to atomic excitations and different types of (sometimes interfering) interactions of the emitted or scattered electrons resulting in energy losses is very difficult (if not impossible). On the other hand, a proper and correct interpretation of electron spectra opens the way to attain a significant improvement in the general accuracy of the quantitative surface analytical applications of electron spectroscopies. In order to develop practically useful models for describing the processes reflected in the electron spectra, usually strong approximations and assumptions, based more or less on experimental observations, are made [1–3]. The first such assumption is that the contributions due to effects of intrinsic (localised around the initial core hole) nature are independent and therefore separable from contributions due to effects of extrinsic nature, i. e. from parts of electron spectra distorted by electron transport. A further assumption is associated with the extrinsic effects, namely that electrons transferring momenta (suffering large changes of direction) during interactions lose only negligible energy (elastic scattering) while electrons losing considerable energy upon interaction change their direction only in a negligibly small extent (inelastic scattering). This assumption is valid for medium energy electrons and is supported by theoretical models treating elastic electron scattering as a scattering of electrons on the screened Coulomb field of the atomic nucleus and describing inelastic electron scattering in terms of collective excitation of electrons in the dielectrics. On its way out of the solid the electron experiences changes in the probability of excitations at the surface, where two-dimensional modes of charge oscillations can be induced at the expense of energy loss of the electron crossing the surface or interface (surface loss). These different origin (bulk, surface and intrinsic) contributions to the energy loss part of the electron spectra (intrinsic losses occur only in the XPS or AES spectra, as a consequence of the sudden appearance of the core hole(s)) are supposed to be attributable to uncorrelated processes

[1–3] and therefore removable from the spectra by successive deconvolutions [3–5]. A careful analysis of experimental and model REELS spectra allows to obtain information on the relation between processes leading to surface and bulk losses. In describing surface excitations an important quantity is the average number of surface excitations an electron experiences when crossing the surface once, called surface excitation parameter (SEP) [6]. The probability for multiple surface excitations follows a Poisson distribution [7], therefore the probability for producing a given number surface excitations can be derived from the SEP. For obtaining the SEP values as a function of the angle of surface crossing and the energy of the electron in the case of different solids, various predictive formulas were proposed [6,8,9] while the SEP was also predicted by the theoretical model of Tung [10] on the basis of a Drude-Lindhard type expansion of the optical loss function. For nearly free electron materials the SEP values derived from experimental REELS spectra [11,12] agree satisfactorily with those obtained from the predictive formula given in [6]. A novel method to analyse REELS spectra, allowing to study the inelastic electron–solid interaction in significantly more detail in the case of medium energy electrons, has been developed recently [13–15]. The method makes possible the observation of the *begrenzungs* effects, i.e. the reduction of the intensity of bulk modes due to the coupling with surface modes [13]. This novel procedure for evaluation of REELS spectra provides the distribution of energy losses in a single surface excitation in absolute units without the use of any fitting parameters in agreement with the theoretical model of Tung [10,13,14]. Using this method for decomposition of the experimental REELS spectra into contributions from surface and bulk excitations, it was found that the surface excitation probability depends not only on the angle of the incident and emitted electrons, but also on the scattering angle. This implies deviations of the electron path (when crossing the surface region) from the rectilinear trajectory and that the multiple surface excitations deviate from the Poisson distribution [15].

In the present work high energy resolution REELS spectra are presented for the wide primary

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