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Secondary Electron Production and Transport Mechanisms By Measurement of Angle-Energy Resolved Cross Sections of Secondary and Backscattered Electron Emission from Gold

Jason T. Kite

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Jason T. Kite

A dissertation submitted in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

In

Physics

Dr. J. R. Dennison Major professor	Dr. D. Mark Riffe Committee member
Dr. John W. Raitt Committee member	Dr. Charles Swenson Committee member
Dr. Jan J. Sojka Committee member	Dr. Byron R. Burnham Vice Provost and Dean of Graduate Studies

Utah State University

Logan, Utah

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Major Professor: Dr. J.R. Dennison

Department: Physics

Abstract: This work provides information about interactions that produce emitted electrons from polycrystalline Au. Emission energy- angle- dependent electron spectra from a polycrystalline Au surface have been measured at several incident electron beam energies. The range of incident energies (~100 eV to 2500 eV) extends from below the first crossover energy, through E_{max}, to above the second crossover energy. The conventional distinction between secondary electrons (SE) (<50 eV) and backscattered electrons (BSE) (>50 eV) is found to be crude for the investigation of electron yields using these energy- angle- resolved measurements. A more realistic boundary occurs at the local minima of the emission spectra; this feature is studied as a function of incident energy and emission angle. In addition, deviations observed in the angular resolved emission spectra from isotropic behavior suggests that residual signatures exist in the emission spectra resulting from the anisotropic SE production mechanisms. Based on the disparity between our observations and recent modeling of the emission spectra, the most recent theory and simulation studies may overestimate the occurrence of randomizing collisions of scattered secondary electrons in the model of the transport mechanism. Finally, description of extensive modification to instrumental and analysis methods are described, and their effectiveness is evaluated.

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ABBREVIATIONS, SYMBOLS, AND NOTATION

AR angle-resolved

AI angle-integrated

BSE backscattered electron

CA chamber apparatus

DAQ data acquisition

EDX energy-dispersive x-ray

ER energy-resolved

ESA electron-stimulated adsorption

ESD electron-stimulated desorption

HV high voltage

IP inelastic peak

LET low-energy tail

PE primary electron

QM quantum mechanical

RD rotatable detector

RGA residual gas analyzer

SE secondary electron

SEE secondary electron emission

SEM scanning electron microscope

UHV ultra-high vacuum

$\vec{E}$ ambient electric field

$\vec{B}$ ambient magnetic field

α emission angle

E_B incident electron beam energy

Φ_{RD} sample bias

$d\Omega$ solid angle subtended by the RD

$n(x,E_0)$	average number of SE's produced per incident PE in a layer of thickness *dx* at a depth *x* below the surface
$f(x)$	probability for an SE to migrate to the surface from a depth *x* and escape
$\frac{-dE}{dx}$	average PE energy loss per unit path length (stopping power)
δ_{max}	maximum SE yield for a given material
E_{max}	incident energy at which δ_{max} occurs
φ_{RD}	detector position
E_e	emitted energy
δ	total SE yield
δ_{AER}	angle-energy-resolved SE yield
δ_{AR}	angle-resolved SE yield
δ_{ER}	energy-resolved SE yield
$\delta(\alpha')$	AR SE yield
$\delta(\alpha)$	SE angular distribution function
$\delta(E_e')$	energy-resolved SE yield
$\delta(E_e)$	SE energy distribution function
$\delta(\alpha',E_e')$	angle-energy-resolved SE yield
$\delta(\alpha',E_e)$	AR SE energy distribution function
$\delta(\alpha,E_e')$	energy-resolved SE angular distribution function
$\delta(\alpha,E_e)$	SE angle and energy distribution function
η	total BSE yield
$\eta(\alpha')$	AR BSE yield
$\eta(\alpha)$	BSE angular distribution function
$\eta(E_e')$	energy-resolved BSE yield
$\eta(,E_e)$	BSE energy distribution function

$\eta(\alpha',E_e')$	angle-energy-resolved BSE yield
$\eta(\alpha',E_e)$	AR BSE energy distribution function
$\eta(\alpha,E_e')$	energy-resolved BSE angular distribution function
$\eta(\alpha,E_e)$	BSE angle and energy distribution function
σ	total emitted electron yield ($\delta+\eta$)
$\sigma(\alpha')$	AR total emitted yield
$\sigma(\alpha)$	emitted-electron angular distribution function
$\sigma(E_e')$	energy-resolved emitted-electron yield
$\sigma(E_e)$	emitted-electron energy distribution function
$\sigma(\alpha',E_e')$	angle-energy-resolved emitted-electron yield
$\sigma(\alpha',E_e)$	AR emitted-electron energy distribution function
$\sigma(\alpha,E_e')$	energy-resolved emitted-electron angular distribution function
$\sigma(\alpha,E_e)$	emitted-electron angle and energy distribution function