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Surface chemical analysis — Auger electron spectroscopy — Derivation of chemical information

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National foreword

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TECHNICAL REPORT

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Surface chemical analysis — Auger electron spectroscopy — Derivation of chemical information

Analyse chimique des surfaces — Spectroscopie des électrons Auger — Déduction de l'information chimique

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Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
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Foreword

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The committee responsible for this document is ISO/TC 201, *Surface chemical analysis*, Subcommittee SC 7, *Electron spectroscopies*.

This second edition cancels and replaces the first edition (ISO/TR 18394:2006), which has been technically revised.

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Introduction

This Technical Report provides guidelines for the identification of chemical effects on X-ray or electron-excited Auger-electron spectra and for using these effects in chemical characterization.

Auger-electron spectra contain information on surface/interface elemental composition as well as on the environment local to the atom with the initial core hole[1][2][3][4][5]. Changes in Auger-electron spectra due to alterations of the atomic environment are called chemical (or solid-state) effects. Recognition of chemical effects is very important in proper quantitative applications of Auger-electron spectroscopy and can be very helpful in identification of surface chemical species and of the chemical state of constituent atoms in surface or interface layers.

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Surface chemical analysis — Auger electron spectroscopy — Derivation of chemical information

1 Scope

This Technical Report provides guidelines for identifying chemical effects in X-ray or electron-excited Auger-electron spectra and for using these effects in chemical characterization.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 18115 (all parts), *Surface chemical analysis — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18115 (all parts) apply.

4 Abbreviated terms

CCC	core-core-core (Auger-electron transition)
CCV	core-core-valence (Auger-electron transition)
CK	Coster-Kronig
c-BN	cubic boron nitride
CVV	core-valence-valence (Auger-electron transition)
DEAR-APECS	Dichroic Effect in Angle Resolved Auger-Photoelectron Coincidence Spectroscopy
h-BN	hexagonal boron nitride
IAE	Interatomic Auger Emission
ICD	Interatomic Coulomb Decay
PAES	Positron-Annihilation-induced Auger Electron Spectroscopy
REELS	Reflection Electron Energy-Loss Spectroscopy

5 Types of chemical and solid-state effects in Auger-electron spectra

Many types of chemical or solid-state effects can be observed in Auger-electron spectra[1][2][3][4][5]. Changes in the atomic environment of an atom ionized in its inner shell can result in a shift of the kinetic energy of the emitted Auger electron. In the case of X-ray-excited Auger-electron spectra, energy shifts of Auger parameters (i.e. kinetic-energy differences between Auger-electron peaks and the photoelectron peaks corresponding to the core levels involved in the Auger-electron process) can be detected as well. Furthermore, the line shape, the relative intensity and the satellite structure (induced by the intrinsic

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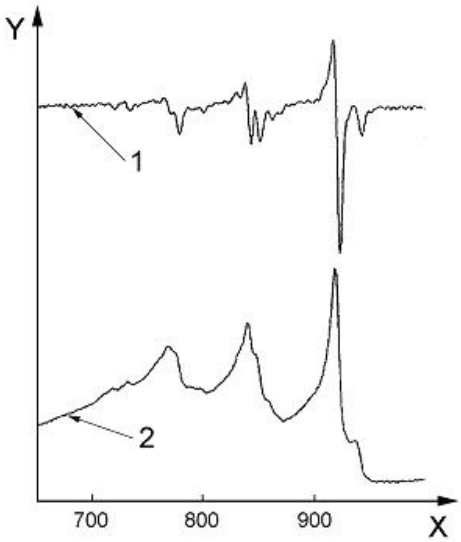
excitation processes) of the Auger-electron lines can be considerably influenced by chemical effects, as can the structure of the energy-loss region (induced by extrinsic, electron-scattering processes) accompanying the intrinsic peaks. Strong chemical effects on the Auger-electron spectral shapes offer ways of identification of chemical species using the "fingerprint" approach.

In the case of electron-excited Auger-electron spectra, the Auger peaks are generally weak features superimposed on an intense background caused to a large extent by the primary electrons scattered inelastically within the solid sample. As a consequence, the differential Auger-electron spectrum is often recorded (or calculated from the measured spectrum) rather than the direct energy spectrum, facilitating the observation and identification of the Auger-electron peaks and the measurement of the respective Auger transition energies. Differentiation can, however, enhance the visibility of random fluctuations in recorded intensities, as shown in Figure 1. If chemical-state information is needed from a direct energy spectrum, then the relative energy resolution of the electron spectrometer should be better than 0,15 % (e.g. 0,05 % or 0,02 %). A poorer energy resolution causes a significant broadening of the Auger-electron peaks and prevents observation of small changes of spectral line shapes or peak energies as chemical-state effects in the spectra. A great advantage of electron-excited Auger-electron spectroscopy over X-ray excitation with laboratory X-ray source, however, is the possibility of using high lateral resolution and obtaining chemical-state maps of surface nanostructures.

NOTE 1 Auger-electron spectra can be reported with the energy scale referenced either to the Fermi level or to the vacuum level. Kinetic energies with the latter reference are typically 4,5 eV less than those referenced to the Fermi level, but the difference in energies for these two references can vary from 4,0 eV to 5,0 eV since the position of the vacuum level depends on the condition of the spectrometer and may, in practice, vary with respect to the Fermi level. When energy shifts are determined from spectra recorded on different instruments, use of different energy references should be taken into account.

NOTE 2 While the visibility of noise features in a differential spectrum can be reduced by use of a larger number of channels in the calculation of the derivative, there may also be distortion of the resulting differential spectrum and loss of fine details associated with chemical-state effects.



Key

X kinetic energy, eV

Y intensity

1 differential spectrum

2 direct spectrum

NOTE This figure is reproduced from Figure 2.8 of Reference [1].

Figure 1 — Comparison of direct and differentiated Auger-electron spectra for copper (Cu LMM peaks)

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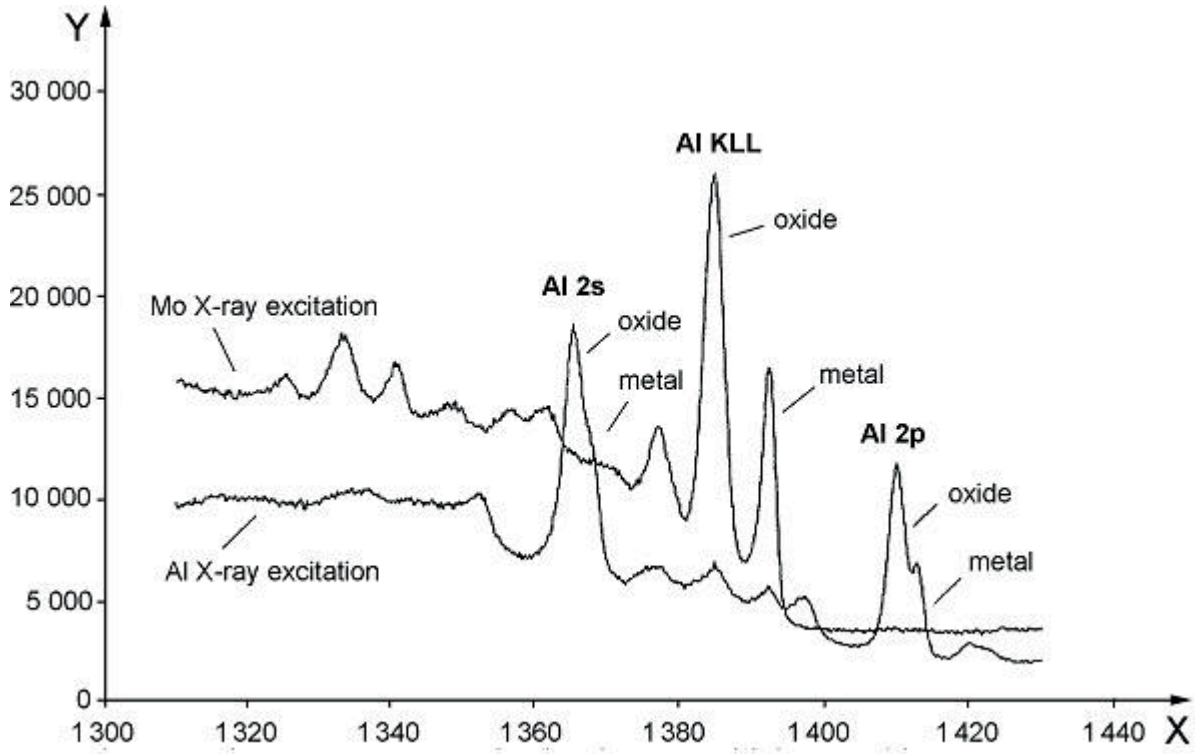
6 Chemical effects arising from core-level Auger-electron transitions

6.1 General

Core-level (or core-core-core, CCC) Auger-electron transitions occur when all of the levels involved in the Auger transition belong to the atomic core for the atom of interest.

6.2 Chemical shifts of Auger-electron energies

The main effect of any change in the solid-state environment on Auger-electron spectra for Auger transitions involving core levels is a shift of the Auger energies. This shift results from a change in the core atomic potential due to the changed environment and from a contribution due to the response of the local electronic structure to the appearance of core holes. Auger chemical shifts are generally larger than the binding-energy shifts of the atomic levels involved in the Auger-electron process because the two-hole final state of the process is more strongly influenced by relaxation effects. This phenomenon is illustrated by the example of aluminium and its oxide in Figure 2[6]. Large chemical shifts in the energy positions of the Auger-electron lines provide possibilities for chemical-state identification even in the case of electron-excited Auger-electron spectroscopy with, in this case, moderate energy resolution. In X-ray-excited Auger-electron spectra, the peak-to-background intensity ratios are usually larger than those in electron-excited spectra, facilitating accurate determination of peak energies. Recommended Auger electron energies are available for 42 elemental solids[7]. Information on Auger chemical shifts of particular elements can be obtained from handbooks[8][9][10][11] and online-accessible databases[12][13].



Key

X kinetic energy, eV

Y intensity, counts/s

Figure 2 — Photoelectron and Auger-electron spectra of an aluminium foil covered by a thin overlayer of aluminium oxide: Excitation with Al and Mo X-rays

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