ASTM INTERNATIONAL

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Standard Guide for
Background Subtraction Techniques in Auger Electron Spectroscopy and X-Ray Photoelectron Spectroscopy[1]

This standard is issued under the fixed designation E995; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The purpose of this guide is to familiarize the analyst with the principal background subtraction techniques presently in use together with the nature of their application to data acquisition and manipulation.

1.2 This guide is intended to apply to background subtraction in electron, X-ray, and ion-excited Auger electron spectroscopy (AES), and X-ray photoelectron spectroscopy (XPS).

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E673 Terminology Relating to Surface Analysis (Withdrawn 2012)[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology E673.

4. Summary of Guide

4.1 *Relevance to AES and XPS:*

4.1.1 *AES*—The production of Auger electrons by bombardment of surfaces with electron beams is also accompanied by emission of secondary and backscattered electrons. These secondary and backscattered electrons create a background signal. This background signal covers the complete energy spectrum and has a maximum (near 10 eV for true secondaries), and a second maximum for elastically backscattered electrons at the energy of the incident electron beam. An additional source of background is associated with Auger electrons, which are inelastically scattered while traveling through the specimen. Auger electron excitation may also occur by X-ray and ion bombardment of surfaces.

4.1.2 *XPS*—The production of electrons from X-ray excitation of surfaces may be grouped into two categories—photoemission of electrons and the production of Auger electrons from the decay of the resultant core hole states. The source of the background signal observed in the XPS spectrum includes a contribution from inelastic scattering processes, and for non-monochromatic X-ray sources, electrons produced by Bremsstrahlung radiation.

4.2 Various background subtraction techniques have been employed to diminish or remove the influence of these background electrons from the shape and intensity of Auger electron and photoelectron features. Relevance to a particular analytical technique (AES or XPS) will be indicated in the title of the procedure.

4.3 Implementation of any of the various background subtraction techniques that are described in this guide may depend on available instrumentation and software as well as the method of acquisition of the original signal. These subtraction methods fall into two general categories: (*1*) real-time background subtraction; and (*2*) post-acquisition background subtraction.

5. Significance and Use

5.1 Background subtraction techniques in AES were originally employed as a method of enhancement of the relatively weak Auger signals to distinguish them from the slowly varying background of secondary and backscattered electrons. Interest in obtaining useful information from the Auger peak line shape, concern for greater quantitative accuracy from Auger spectra, and improvements in data gathering techniques, have led to the development of various background subtraction techniques.

5.2 Similarly, the use of background subtraction techniques in XPS has evolved mainly from the interest in the determination of chemical states (from the binding-energy values for component peaks that may often overlap), greater quantitative accuracy from the XPS spectra, and improvements in data acquisition. Post-acquisition background subtraction is normally applied to XPS data.

5.3 The procedures outlined in Section 7 are popular in XPS and AES; less popular procedures and rarely used procedures are described in Sections 8 and 9, respectively. General reviews of background subtraction methods and curve-fitting techniques have been published (**1-5**).[4]

5.4 Background subtraction is usually done before peak fitting. Some commercial systems require background removal. Nevertheless, a measured spectral region consisting of one or more peaks and background intensities due to inelastic scattering, Bremsstrahlung (for XPS with unmonochromated X-ray sources), and scattered primary electrons (for AES) can often be satisfactorily represented by choosing functions for each intensity component with parameters for each component determined in a single least-squares fit. The choice of the background to be removed if required or desired before peak fitting is suggested by the experience of the analysts and the peak complexity as noted above.

6. Apparatus

6.1 Most AES and XPS instruments either already use, or may be modified to use, one or more of the techniques that are described.

6.2 Background subtraction techniques typically require a digital acquisition and digital data handling capability. In earlier years, the attachment of analog instrumentation to existing equipment was usually required.

7. Common Procedures

7.1 *Linear Background Subtraction (AES and XPS)*—In this method, two arbitrarily chosen points in the spectrum are selected and joined by a straight line (**1 and 2**). This straight line is used to approximate the true background and is subtracted from the original spectrum. For Auger spectra, the two points may be chosen either on the high-energy side of the Auger peak to result in an extrapolated linear background or such that the peak is positioned between the two points. For XPS spectra, the two points are generally chosen such that the peak is positioned between the two points. The intensity values at the chosen points may be the values at those energies or the average over a defined number of data points or energy interval.

7.2 *Integral (or Shirley) Background Subtraction (AES and XPS)*—This method, proposed by Shirley (**6**), employs a mathematical algorithm to approximate the inelastic scattering of electrons as they escape from the solid. The algorithm is based on the assumption that the background is proportional to the area of the peak above the background at higher kinetic

energy. This basic method has been modified to optimize the required iterations (**7**), to provide for a sloping inelastic background (**8**), to provide for a background based upon the shape of the loss spectrum from an elastically backscattered electron (**9**), and to include a band gap for insulators (**1**).

7.3 *Inelastic Electron Scattering Correction (AES and XPS)*—This method, proposed by Tougaard (**10**), uses an algorithm which is based on a description of the inelastic scattering processes as the electrons travel within the specimen before leaving it. The scattering cross section which enters in the algorithm is taken either from a simple universal formula which is approximately valid for some solids, similar functions that have been optimized for particular materials or material classes (**11**), or is determined from the energy spectrum of a backscattered primary electron beam by another algorithm (**1 and 12**). Alternatively, the parameters used in the universal formula may also be permitted to vary in an algorithm so as to produce an estimate of the background (**1 and 13**). This background subtraction method also gives direct information on the in-depth concentration profile (**14 and 15**). Tougaard has assessed the accuracy of structural parameters and the amount of substance derived from the analysis (**16**). A simpler but more approximate form of the Tougaard algorithm (**17**). can be used for automatic processing of XPS spectra (for example, spectra acquired for individual pixels of an XPS image).

7.4 *Signal Differentiation, dN(E)/dE or dEN(E)/dE (AES)* (**18 and 19**)—Signal differentiation is among the earliest methods employed to remove the background from an Auger spectrum and to enhance the Auger features. It may be employed in real time or in post acquisition. In real time, differentiation is usually accomplished by superposition of a small (1 to 6 eV peak-to-peak) sinusoidal modulation on the analyzer used to obtain the Auger spectrum. The output signal is then processed by a lock-in amplifier and displayed as the derivative of the original energy distribution *N(E)* or *EN(E)*. In post-acquisition background subtraction, the already acquired *N(E)* or *EN(E)* signal may be mathematically differentiated by digital or other methods. The digital method commonly used is that of the cubic/quadratic derivative as proposed by Savitzky and Golay (**20**).

7.5 *X-Ray Satellite Subtraction (for Non-Monochromated X-Ray Sources) (XPS)* (**21**) —In this method, photoelectron intensity from the satellite X-rays associated with the K X-ray spectrum from an aluminum or magnesium X-ray source is subtracted. Intensity is removed from higher kinetic energy channels at the spacing of the $K\alpha_{3,4}$, $K\beta$, etc. satellite positions from the $K\alpha_{1,2}$ main peak and with the corresponding intensity ratios (**21**) to remove their contributions to the XPS spectrum. This subtraction can proceed through the spectrum but not if there is an Auger peak in the region of interest because it would erroneously remove an equivalent intensity from any Auger peaks present in the spectrum.

7.6 *Implementation of the Linear, Integral, and Tougaard Background Subtraction Methods (XPS)*—A key choice in implementation of the linear (7.1), integral (7.2), and Tougaard (7.3) background subtraction methods is the selection of the two end points or spectral region for background subtraction.

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[4] The boldface numbers in parentheses refer to the references at the end of this standard.