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LETTER

THE APPLICATION OF DIGITAL TECHNIQUES FOR ELECTRON ENERGY SPECTROSCOPY USING A RETARDING FIELD ANALYSER

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This letter presents a method for digitizing the collector signal of a LEED-optics system, used in the retarding field analyser mode. The transformation of a current into a digital signal with a sufficient dynamic range and the modifications needed for the reduction of noise are discussed. The performance of such a system is tested on a three-grid LEED–Auger retarding field analyser having an energy resolution of $\Delta E/E = 2.5\%$. As an example, Auger spectra of aluminium films on a carbon substrate are shown.

LEED optics are used to investigate the crystal structure of surfaces by electron diffraction, but are as well applied as a retarding field analyser (RFA) to perform electron energy spectroscopy from solid surfaces. The electron energy spectra contain Auger peaks (AES) which provide information about the surface composition and energy loss features (EELFS) giving information about interatomic distances as in EXAFS [4,6]. However, a RFA displays the integrated electron energy spectrum. The energy spectrum itself is obtained by differentiation. In order to separate the spectroscopic structures from the background, the collected signal is usually differentiated twice, yielding the first derivative of the energy spectrum.

A common differentiation technique is modulation of the retarding field with an AC voltage of properly chosen frequency and amplitude [2]. The resulting modulation of the electron current at the collector is measured by a tuned lock-in amplifier [1]. By expanding the current as a function of energy in a Taylor series, it can be seen that to first approximation the amplitude of the first harmonic of the modulated signal is proportional to the first derivative of the collected electron current. The amplitude of the second harmonic is proportional to the second derivative. The proportionality constants were derived by Taylor [2]. He assumed a Gaussian energy distribution for the

Auger peak, containing a total current i. In order to keep the proportionality of the second derivative within 20%, a modulation amplitude $\leq$ the full-width at half-height was chosen. This resulted in a maximum amplitude in the current of the second harmonic of 5% of i. Because of this loss of signal, primary electron currents larger than 10 μA have to be used in order to keep measuring times within reasonable limits. The sensitivity can be improved by the choice of a larger modulation voltage amplitude. This will not only result in a further loss of proportionality, but also in a decreasing energy resolution.

An accurate determination of Auger electron energies from differentiated spectra is difficult; the peak positions obtained after differentiation correspond to the positions of the points of inflection of the original peaks. The positions of these points do not only depend on the natural width of the lines, but also on the energy resolution of the analyser and the amplitude of the modulation voltage.

Another problem is the loss of quantitative information on surface composition, which arises from taking the derivative of the energy spectrum [3]. From this point of view it is better to store the signal in a multichannel analyser [3] or a computer [5,7], followed by a digital differentiation procedure. By application of some background subtrac-

tion procedure, the Auger peaks can be extracted from the resulting spectra. This technique has been demonstrated using an electrostatic deflection analyser such as a CMA [5]. These analysers are provided with an electron multiplier, giving pulses at the output, which can easily be digitized. A disadvantage of these analysers is the low transmission ($\div E \times N(E)$) in the low energy region.

The first attempts to use digital techniques applying a RFA to perform AES, were made by Staib and Kirschner [3]. They used an ADC to digitize the amplitude of the first harmonic extracted from a lock-in amplifier. The background could be subtracted and the Auger peaks were revealed. However, by using the first harmonic, it is calculated by Taylor [2] that only 20% of the available current in the Auger peak is utilized.

We attempted to digitize the collector current from a RFA directly, with the use of an ADC. However, the dynamic range proved to be too small to distinguish Auger signals in the integrated energy spectrum from the large background. Therefore, we have choosen a current-to-frequency convertor (ATC model 170) which operates with currents from 5×10^{-6} to 10^{-14} A in three ranges, with a dynamic range of 5×10^6. The digitized frequency was fed into the computer. In addition, some modifications had to be made to the RFA itself.

An important contribution to the total signal is from secondary electrons produced at the material of the grids. Dependent on the potentials in the system, these electrons can reach the collector, where they contribute to the collector current. In order to reduce the yield of secondary electrons, all grids are covered by a carbon film of 1000 Å thickness. Deposition of carbon is performed by e^- beam evaporation of graphite.

An undesirable background also arose from leakage currents over the insulating ceramic spacers between grids and collector. Usually, the collector is biased to +200 eV to prevent scattering of arriving electrons as well as emission of secondary electrons. Leakage currents could be reduced by choosing a low collector potential. Scattering effects and emission of secondaries were suppressed by applying a thick layer of soot at the collector surface, which acts as a sponge for elec-
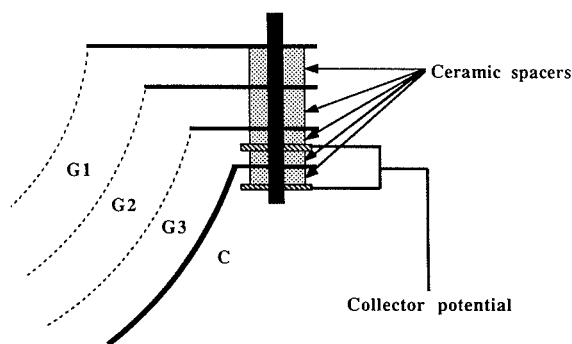

Fig. 1. Schematic layout of the grid assembly of the LEED–Auger retarding field system. The stainless steel washers which are kept at earth potential, prevent leakage currents from reaching the collector C. The collector C is coated with a thick layer of soot, which prevents back scattering. The grids G1, G2 and G3 are provided with a carbon coating so as to reduce scattering of primary electrons as well as the production of secondary electrons.

trons. The soot layer was covered by fluorescent material to allow for LEED measurements. After these modifications a collector bias between 0 and +10 eV was to be applied. As no modulation voltage is used, the scanning potential can be applied to both G2 and G3, resulting in a better energy resolution. This causes a residual leakage current to the collector, which was reduced by dividing the ceramic insulator between grid 3 and the collector in two parts and inserting a metal washer at collector potential (fig. 1).

With the modified RFA system, Auger spectra were taken from aluminium films, grown on a carbon substrate with different layer thicknesses. The primary energy was 1520 eV and the current density was 5×10^{-5} A/mm². The Auger electron energy spectra are shown in fig. 2, with their backgrounds, obtained by curve fitting, removed. The AlMNN peak near 52 eV originates from carbide [8] and the peak near 64 eV from pure aluminium. Each of the spectra consists of 100 energy scans, with each scan taken in steps of 1 eV and a measuring time of 0.02 s/point. This corresponds to a total beam dose of 10^{-2} C/mm² per spectrum. By comparison, for the acquisition of a differentiated spectrum over the same energy range by lock-in techniques, a total irradiation of 2×10^{-1} C/mm² was needed. The observed reduction of dose by a factor 20, which results from the use
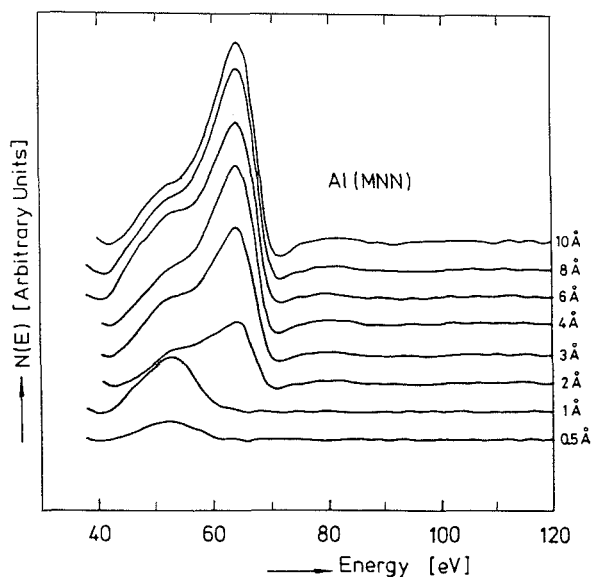
Fig. 2. Auger MNN energy spectra ($N(E)$) from aluminium films deposited on a carbon substrate, with thicknesses ranging from 0.5 to 10 Å. Backgrounds were obtained by curve fitting and were subtracted from the original spectra.

of digital techniques, is roughly the gain in signal as expected from Taylor's analyses [2].

In the near future this modification will be applied to a (RFA) LEED–Auger system having an energy resolution of 0.5%.

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