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CVV AUGER LINE SHAPES IN ALUMINIUM

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Aluminium $L_{23}VV$ and KVV Auger spectra are compared for the first time. In spite of the differences in kinetic energy of the escaping electrons and of the core-holes, the two spectra look very similar suggesting that surface effects do not contribute much to the Auger transition. Moreover in both spectra it is visible a high energy structure which is interpreted as an intrinsic plasmon-grain satellite due to the core-hole relaxation.

ALTHOUGH in the last years there has been a great deal of work on the CVV (Core–Valence–Valence) Auger spectra in simple metals [1–6, 14], we believe that a satisfactory understanding of these line shapes has not been gained yet. Among the variety of problems which make the interpretation of these spectra difficult, it is important to account for surface effects and their relation to the bulk properties. In fact the vicinity of the sample surface to the Auger-electron origin affects both the excitation and the escape of the electrons and it appears very difficult to assess the importance of the coupling of core, valence and Auger electrons with the surface electron states and the surface plasmons. In any case such a coupling could affect the shape of the Auger spectrum with the same mechanism as the bulk plasmons [3]. Moreover inelastic scatterings can occur also at the surface, the loss function of which is different from that of the bulk.

A large body of experimental high quality information on the aluminium $L_{23}VV$ Auger spectrum is already available [14], instead the KVV line has never been reported in literature because of its very weak intensity. On the other hand a comparison between the two processes is highly desirable because they are expected to exhibit different behaviours due to different bulk and surface characters. The KVV Auger electrons, expelled in the relaxation of an s-core hole, have an energy as high as 1500 eV and then a mean free path of 30 Å [8], so that it is reasonable to expect a bulk contribution predominant. Otherwise the $L_{23}VV$ Auger electrons, corresponding to a p-core hole, have a much smaller energy and a mean free path of the order of 4 Å [8], so that now the surface should play a more important role than in the KVV case.

Bearing this in mind, it has been performed a detailed experimental investigation of both KVV and $L_{23}VV$ Auger transitions in aluminium. A PHI 600 Scanning Auger Microprobe with a base pressure of 2×10^{-10} Torr was used in concomitance with a cylindrical mirror analyzer with 0.3% energy resolution. The core hole was produced by means of electron excitation in the energy range from 1 to 25 keV. The sample was pure polycrystalline aluminium and before the experiment it was kept under vacuum for many days. Several measurements on both KVV and $L_{23}VV$ lines have been performed, lasting from 10 to 30 min each, checking the major contaminants like oxygen, nitrogen and carbon before and after each measurement. In all cases very little contamination of carbon has been observed, while the content of other contaminants has been kept below the machine sensitivity by argon sputtering before each run. Several excitation energies E_p have been employed and, according to Langeron *et al.* [9], it has been obtained a good peak-to-background ratio for $E_p/E_a > 10$, E_a being the Auger energy. Therefore we used $E_p =$ 3 keV to excite the $L_{23}VV$ line and $E_p = 25$ keV in the case of the KVV line. In Figs. 1 and 2 the electron fluxes per unit time and energy are shown after a simple background subtraction obtained by smoothly joining the tails of the spectrum. Certainly this subtraction procedure is not the most correct one, but our present investigation concerns the comparison of

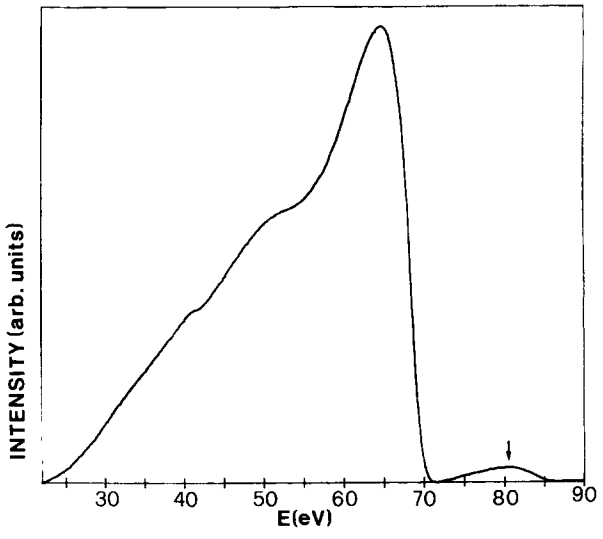

Fig. 1. Electron excited $L_{23}VV$ Auger spectrum of aluminium. The arrow indicates the plasmon-gain satellite.

KVV and $L_{23}VV$ spectral features which are not strongly dependent on the electron kinetic energy and so almost independent from the cleaning operations. In the case of the $L_{23}VV$ line, an energy step of 0.2 eV was used, while for the KVV line, because of the very low intensity, an energy step of 3 eV has been employed.

At present, it is not possible to establish exactly the intensity ratio of the two spectra as we did not succeed in observing the KVV line at low exciting electron energy $E_p < 15$ keV. It has been chosen to measure the $L_{23}VV$ line at relatively low incident energy because the machine stability is much better

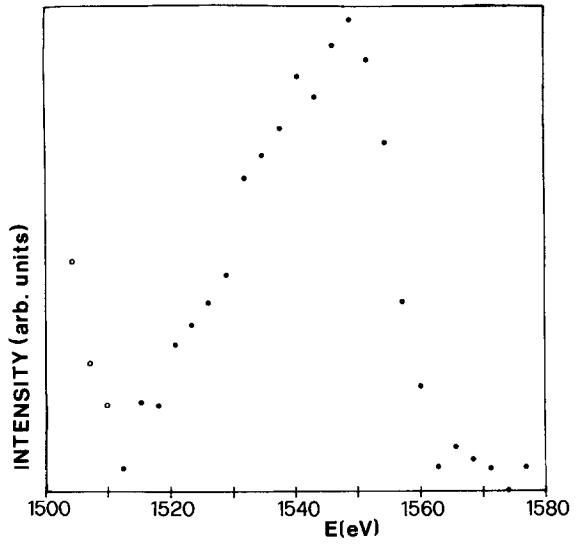

Fig. 2. Electron excited KVV Auger spectrum of aluminium. Rising open circles at low energy are due to the tail of the much stronger $KL_{23}V$ Auger line.

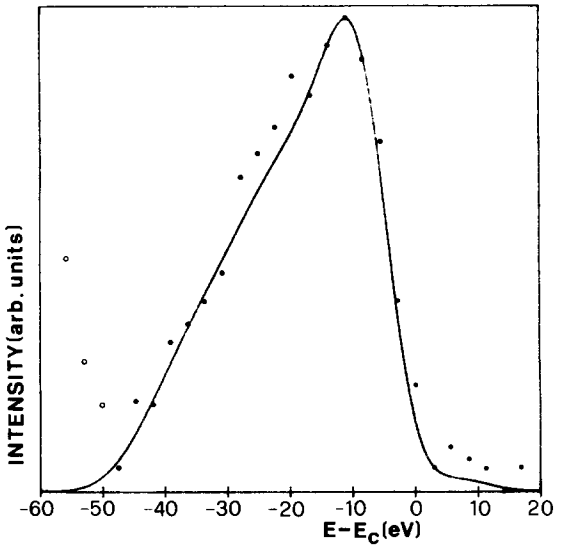

Fig. 3. Comparison of $L_{23}VV$ (solid line) and KVV (dots) spectra at the same resolution; E_c is the core energy level set at 74 eV and 1560 eV for L_{23} and K levels respectively. Open circles as in Fig. 2.

and in order to reduce the number of the L_{23} holes too deeply created into the sample because they do not contribute to the no-loss spectrum but contribute much more to the background. However we estimate the KVV to $L_{23}VV$ intensity ratio to be 8×10^{-4} on the peak which is in good agreement with the estimate of Houston [2].

As we can see from Figs. 1 and 2, the two spectra look very similar, the width being essentially the same. However it must be observed that the energy resolution on the $L_{23}VV$ line is 0.2 eV, while on the KVV line is 4.5 eV, so that no one-to-one comparison can be made without taking this in account. In fact the steeper trend in the high energy side of the $L_{23}VV$ line as compared to the KVV one is certainly to be ascribed to the worse resolution on the KVV spectrum. To compare the two transitions, the $L_{23}VV$ spectrum was convoluted with a Gaussian resolution of 4.5 eV full width at half maximum, to simulate on it the resolution actually used in the case of the KVV line. The result of this comparison is shown in Fig. 3 where it is evident that the two spectra closely resemble each other. Therefore we can state that the measured CVV spectra are to be connected mainly with bulk electronic structure of aluminium and little contribution should be ascribed to surface states. This conclusion in in agreement with the electron energy-loss data [13] from which one can infer that the bulk-to-surface ratio of the features intensity is about 2.5 at $E_a = 70$ eV, while it is greater than 20 at $E_a = 1500$ eV.

From Fig. 3 it is also evident the presence of a

weak structure on the high energy side of the main peak whose intensity is greater in KVV line than in the $L_{23}VV$ line (although it is cleaner in the $L_{23}VV$ spectrum, Fig. 2, due to the better resolution and statistics). Within the present statistics the observed structure is at the limit of the experimental sensibility in the case of the KVV spectrum; nevertheless we are quite confident that it is present in the worse case too because the background has been measured up to 1700 eV and appeared to be very smooth. Moreover notice that the presence of satellite is independent of the cleaning procedure and in fact it is already visible in the raw data. The mentioned satellites are situated at 80 eV in the $L_{23}VV$ spectrum and at 1565 eV in the KVV spectrum, i.e. 15 eV above the main Auger peak in accordance with the measurement of Chiarello *et al.* [12]. This shift is very close to the bulk plasmon energy in aluminium. The position coincidence of the two peaks makes improbable the explanation of their origin as due to double-ionization satellites. Moreover *extrinsic* plasmon-gain mechanism, i.e. energy-gain scattering of the escaping electrons with the plasmon gas, cannot be employed to explain the observed situation because only loss-structures and no grain-structures are present in the spectra of backscattered electrons. Instead the evidenced structures are to be ascribed to *intrinsic* plasmon-gain, i.e. interaction of the relaxing core-hole with both electrons and plasmons. Model calculations of complete Auger transition (i.e. from the core-hole creation to the Auger-electron escaping) [4, 5, 15] show that the spectral density of the interacting core-hole state develops, during the relaxation, a high energy peak due essentially to the same effect that produces a coupled propagation of core-electrons and plasmons [10, 11], named a plasmaron. The lifetime of both K and L_{23} core states in aluminium appears to be rather long so that the relative Auger spectra are expected to contain all the features of the relaxed core-hole states. Moreover the intrinsic plasmon-gain phenomena are strongly connected with the electron number density (a parameter which well classify the interacting many-body characteristics of an electron gas) so that the observation of a similar structure in KVV spectrum of berillium [4] seems to provide major support to the present interpretation.

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