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AUGER ELECTRON EMISSION DUE TO INCIDENT PARTICLE IN Ar^+, Ne^+ AND Na^+ COLLISIONS WITH DIFFERENT SOLID TARGETS

C. Benazeth, N. Benazeth, L. Viel, C. Leonard

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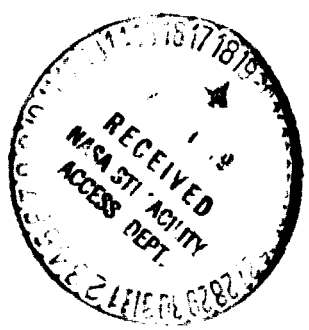

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Annotation

The L_{23} Auger spectra of argon, neon and sodium have been obtained, during collisions between these ions and different solid targets. The argon Auger electrons are emitted by the projectile itself, and Doppler broadening is observed. The Auger spectra due to neon and sodium are characteristic of transitions which take place on implanted neon atoms or surface trapped Na atoms.

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C. Benazeth, N. Benazeth, L. Viel, C. Leonard
Solid State Physics Laboratory, Paul-Sabatier University, Toulouse

The energy distributions of secondary electrons, emitted /253* during the interaction of a beam of ions (or neutrons) and solid targets, in some cases, bring out the existence of electrons of characteristic energy, due to radiationless recombination of vacancies produced in the inner electron shells of either the incident ion or the target atom.

After having studied the Auger structures of the target atom [1-3], we now present results which concern Auger emission due to the incident particle, in the case of collisions between Ar^+, Ne^+ and Na^+ (from a few kiloelectron volts to 100 keV) and various solid targets. These results were obtained in a previously described experimental unit [3]. The angle of incidence of the ion beam on the target is 60^o. The ionic density on the sample is several microamperes per square millimeter.

Results and Interpretation

A. Analysis of Auger Spectra. Characteristic Auger Electrons of Argon

Fig. 1 shows the Auger spectra due to argon, obtained in /254 Ar^+-Ti collisions, after substraction of the continuum background of the energy distribution N(E). The large structure centered at 212 eV, the width of which increases with incident particle energy, is attributed to a set of consecutive Auger transitions, in the recombination of a vacancy in the 2p shell [4].

Characteristic Auger Electrons of Neon

Auger structures due to neon and the target atom appear in the energy distribution of secondary electrons emitted during

* Numbers in the margin indicate pagination in the foreign text.

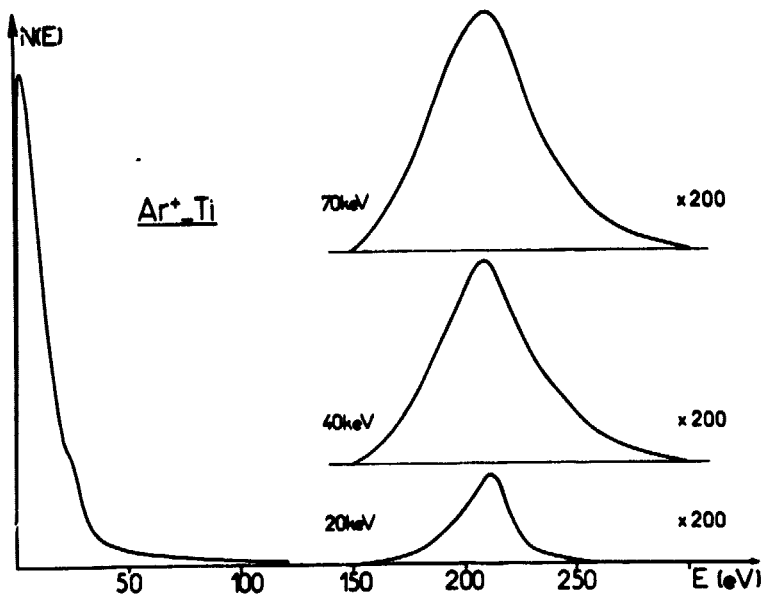

Fig. 1. L_{23} Auger spectrum of argon (continuum background of distribution N(E) subtracted) in Ar^+-Ti collisions vs ion energy.

Ne^+-Mg and Ne^+-Al collisions. The Auger spectrum of neon is located between 20 and 35 eV (Fig. 2a). Essentially, it is made up to two peaks, centered at 22 eV (peak 1) and 25.5 eV (peak 2). The width of these peaks at half height is 2 eV, i.e., comparable to the widths of the Auger peaks due to the target atom. When the energy of the incident particle increases, the amplitude of the signal relative to neon decreases rapidly, while that of the Auger peaks corresponding to the target atom increases [3].

We attribute neon peaks 1 and 2 to transitions from the initial states with two vacancies in the 2p shell [5] (state $2s^2\ 2p^4\ 3s^2$ for peak 1), and not to states with one vacancy in the 2s shell, as has been proposed by some authors [6].

Characteristic Auger Electrons of Sodium

The characteristic Auger structures of sodium and the target atom have been determined in Na^+-Be, Na^+-Mg and Na^+-Al collisions. As an example, Fig. 2b gives the Auger spectra which result from Na^+-Al collisions. The structure located between 25 and 38 eV

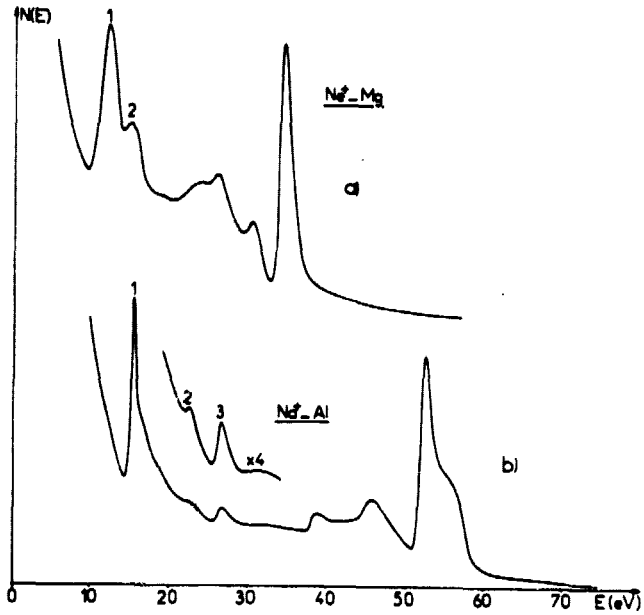

Fig. 2. a. L_{23} Auger spectrum of neon and magnesium obtained during Ne^+(5 keV)-Mg collisions; 1,2. Auger peaks of neon; b. L_{23} Auger spectrum of sodium and aluminum obtained during Na^+(60 keV)-Al collisions; 1, 2, 3. Auger peaks of sodium.

is that of sodium. Essentially, it consists of three peaks centered at 25.5 eV (the strongest peak 1), 32.6 eV (peak 2) and 36 eV (peak 3). These peaks are very narrow, compared to the 0.7 eV of peak 1 at half height. Their position in the energy scale is independent of the energy of the sodium ion. Finally, we note that, in the range of ion energies explored, the amplitude of these bands varies little. Peak 1 is attributed to a $2p^5\ 3s^2 \rightarrow 2p^6$ transition [7]. Peaks 2 and 3 correspond to transitions from doubly ionized initial states in the 2p shell.

B. Origin of Characteristic Auger Emission of Incident Particle

For all the cases presented, study of the molecular orbital correlation diagrams of asymmetrical ion-target atom collisions [8] shows the existence of effective hybridization, which permits the creation of vacancies in the 2p shell of the incident ion. Recombination of the vacancies thus created occurs after the collision on the incident particle, which has only lost a small part of its kinetic energy in the primary collision. Thus, the Auger bands emitted are strongly broadened by the Doppler effect (for example, the broadening is on the order of 20 eV for 20 keV Ar^+ ions (band at about 200 eV) or 40 keV Na^+ ions (25 eV band)). The experimental results are consistent with this type of Auger emission from the so called incident ion, in the case of Ar^+-Ta

collisions. The observed structure should be attributed to a set of L_{23} Auger bands, which are unresolved because they are broadened by the Doppler effect.

On the other hand, in the case of the characteristic Auger electrons of neon and sodium, emission by the incident ion can only explain the wide structure of low amplitude, almost entirely masked by the presence of very intense fine bands superimposed on it. These Auger bands, the energy position and width of which are independent of the velocity of the incident ion in the first approximation, should be attributed to transitions which occur on neon or sodium atoms, which were previously stopped in the solid near the surface, these atoms being ionized in an inner electron shell during symmetrical Ne^+-Ne or Na^+-Na collisions. (We note that, in the case of sodium, a different interpretation recently has been proposed by other authors [9]). With the shallow mean escape depth of 20 and 30 eV electrons (7 to 10 A) given [10], the fact that, in the case of neon, the Auger signal amplitude decreases, while the incident particle energy increases, indicates that the neon atoms which emit electrons are located at distances from the surface which increase with projectile energy. This is characteristic of particles <u>implanted</u> in a solid. In the case of sodium, the narrowness of the Auger peaks (scarcely larger than the instrument broadening) appears to indicate that the effect of the solid on recombination of the inner vacancy is negligible. In connection with the low sensitivity of the Auger signal amplitude to the incident particle energy, we go along with essentially attributing this to Auger emission of sodium atoms trapped on the surface of the sample.

Conclusion

These results have permitted illustration of three different behaviors in the emission of characteristic Auger electrons by the incident particle during ion-solid collisions. In the cases of neon and sodium, Auger spectroscopy study, as a function of various parameters which affect implantation (angle of incidence

of ion beam on the target, temperature and crystallographic nature of the sample), should permit exact determination of the interpretation of the observed phenomena we have proposed and the contribution of information, in particular, on the implantation profiles of the ions very near the surface and the coefficients of diffusion of implanted particles.

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