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ION-INDUCED ATOMIC EXCITATION IN ALUMINUM AND COPPER

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Abstract Light emission from a Cu and Al targets under 5 keV Kr^+ bombardment is studied. AlI and CuI spectral lines show transient at beam-off conditions. The transient curve follows the characteristic of an oxide sputtering.

Keywords: sputtering, optical spectroscopy, surface analysis

1. Introduction

When ion beam of some keV interact with a solid target, sputtering takes place given rise to the ejection of different particles (electrons, neutral and ionic species, aggregates…) [1-5]. Also, ion bombardment of solid targets can lead to the electronic excitation process which may result in the emission of light from the solid. The variation of the line intensity as a function of irradiation time, i.e., transient in photon emission was greatly investigated in the earlier studies for Si [6], FeNi [7], Mg [8] and CuBe [9]. Generally, the enhancement of photon yield can be explained in terms of a simple model, which takes into account the simultaneous adsorption of O_2 on the surface and the removal of oxygen by ion beam sputtering.

In this work we report the results of changes in the line intensity as a function of time due to increase or decrease of oxygen pressure (transient effect) resulting from 5 keV Kr^+ ion bombardment of Cu and Al targets. This study was made in order to understand the emission enhancement effect due to oxygen in more detail.

2. Experimental details

The setup has been described previously [10-13]. The apparatus comprises a VG Model EX05 ion source capable of producing ion beams with intensities up to 6 mA and fluencies up to 50 mA/mm^2 in the energy range 0.1-5 keV. The ion optics comprises two electrostatic lenses and two pairs of deflection plates. At the target, the beam has a minimum diameter of 0.1 mm and can be displaced by 5 mm in both vertical and horizontal directions. Differential pumping is achieved by two turbo-molecular pumps rated at 50 and 200 l/s, respectively. The target chamber is a vertical cylinder with a radius of 125 mm and a height of 143 mm, evacuated by the 200 l/s turbo-molecular pump. The background pressure is less than 10^{-6} Torr. The current density is typically 1.2-1.3 $\mu A/mm^2$. Light is detected at right angle from the ion beam in the plane of incidence. The range of the spectrograph is 190-590 nm. The detector is a photomultiplier, not a diode array, so the time evolution is obtained either by following the intensity of a given atomic line, or by carrying out

partial or complete scans from time to time (a complete scan lasts approximately 15 minutes). The Cu and Al targets are prepared by mechanical polishing and ultrasonic cleaning in ethanol, and then placed in ultra-high vacuum (10^{-7} Torr). Oxygen purity (99.995%) from Air Liquide is used, and introduced in a pressure of 10^{-5} Torr in front of target.

3. Results and discussion

The transients in Fig. 1 and Fig. 2 can be described by the relation given by Bhattacharyya et al. [14],

$$I(\theta) = I_C + (I_O - I_C)\exp\left(-t\Phi_i Y_0 / N_S\right)$$

where $I(\theta)$, I_O and I_C are the photon intensities at an intermediate oxygen covered, at fully oxygen covered and at the clean surface respectively, Φ_i is the flux density of incident ion beam, N_S is the number density of adsorption sites on a random Cu surface and Al surface and Y_0 is the best-fit value which is directly related to the sputtering yield of adsorbed oxygen on Cu and Al. Table 1 depicts the theoretical sputtering yields using TRIM calculations of Cu and Al targets. The sputtering yields obtained from the transient curves are also listed. It is needless to say that the origins of sputtering yields of the above cases are different. In theoretical sputtering yield estimates of Cu and Al at clean surface, in addition to ion interaction, Cu–Cu and Al-Al interactions take place in the collision cascades, whereas sputtering yields from transients are resulted from additional interactions of Cu–O, Al-O and ions-O in the collision cascades.

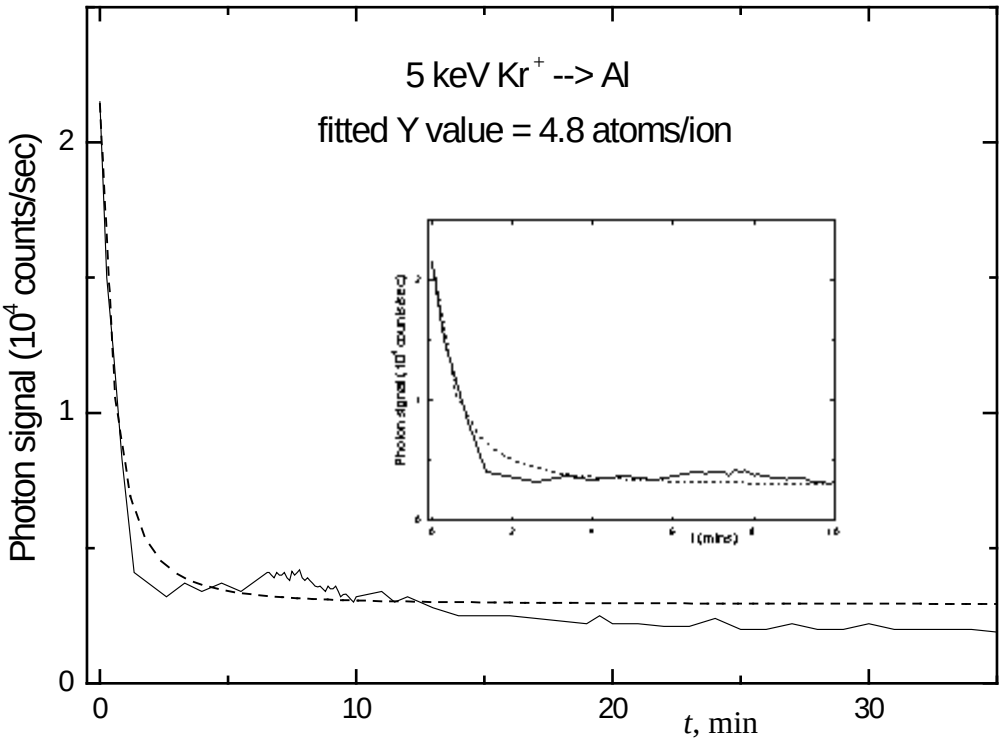

Fig. 1 – Photon yield of the Al 309.3 nm line versus time of bombardment.

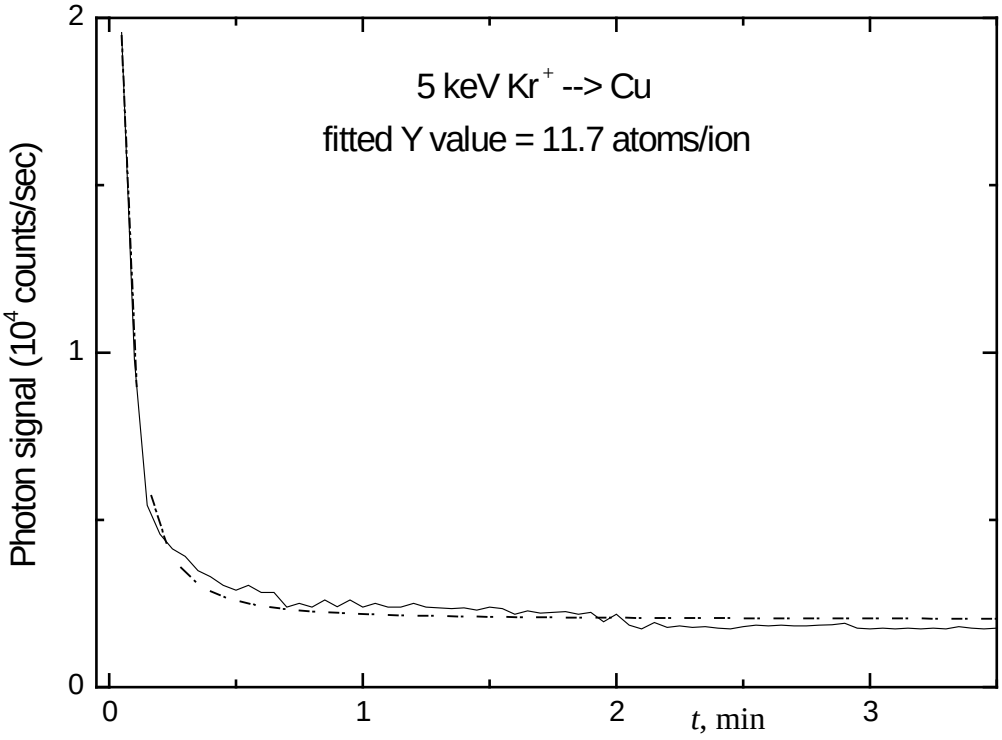

Fig. 2 - Photon yield of the Cu 324.8 nm line versus time of bombardment.

Table 1. Sputtering photon yield for Kr^+.

Ion	Sputtering yields			(atoms/ion)
	SRIM-code (Al-Al)	SRIM-code (Cu-Cu)	Transients (Al-O)	Transients (Cu-O)
Kr^+	8.9	19.4	4.8	11.7

For copper, the general behavior is the same, but the time scale is much shorter: the exponential decrease begins at 40 s and the time constant is 86 s. However. the signal-to-noise ratio is smaller than for aluminium and these numbers are more uncertain.

The exponential decrease and its large time constant do not reflect the initial concentration profile of oxygen atoms which, beyond the rapidly removed oxide layer, is a short diffusion profile. They are consequences of the bombardment which pushes oxygen atoms into the target, delaying their ejection. Furthermore, in the case of aluminium, the oxygen atoms which come to be exposed at the surface easily diffuse to subsurface sites. At every time a surface layer is removed, only a tiny part of the oxygen population is ejected. This gives, at large times, a concentration profile of the form $c_0 g(z) e^{-t/\tau}$ where z is the distance from the surface and c_0 a constant proportional to the

initial population. The function *g* and the time constant τ depend on the characteristics of the collision and diffusion processes, not on the initial state. This explains the difficulty of getting rid of the residual oxygen.

Whereas the Al and Cu signals vary strongly, their ratio I_{Al}/I_{Cu} behaves much more moderately. In the interval 4 s < *t* < 3 min, the deviation from the median value does not exceed 22% (Fig. 3). However, this median value is 70% above the final value and is not fully representative of the "true" intensity ratio.

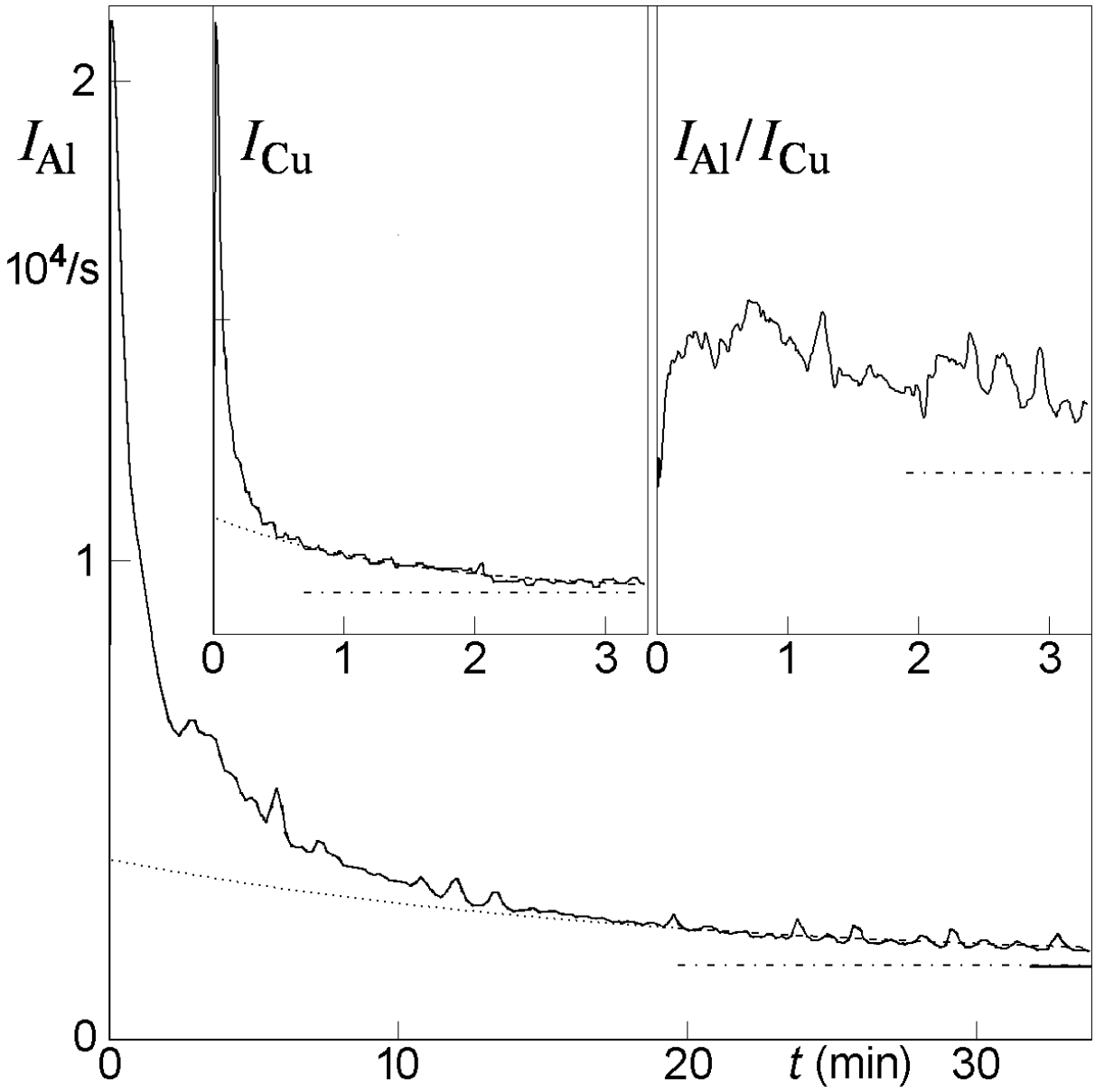

Fig. 3. Main graph: Intensity of the Al 309.3 nm line during the bombardment of an aluminum target. The maximum is reached in 7 seconds. The signal takes about one hour to stabilize. The corresponding level is marked by a short solid line at right hand. Dashed line: exponential plus constant best fitted to the experimental graph over the time interval t > 20 min, giving a time constant 20 min. Dotted line: its continuation at t < 20 min. Dashed-dotted line: the constant (asymptotic value) of the best fit. First insert: Intensity of the Cu I line at 324.8 nm during the bombardment of a copper target. Same conventions are for the discontinuous lines. The time constant is 86 s. Second insert: The ratio of the two intensities in the three first minutes. Dashed-dotted line: the asymptotic value according to the preceding fits.

4. Conclusion

In summary, the results of changes in line intensities from Al and Cu targets as a function of oxygen pressure are presented. In general, at high pressure, the transient curve follows mostly the characteristic of an oxide sputtering.

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