BOMBARDMENT-INDUCED PHOTON EMISSION FROM METALLIC AND SEMICONDUCTING SURFACES AS A FUNCTION OF TARGET TEMPERATURE*

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The results of experiments on bombardment-induced photon emission from a Ge single crystal and two metallic polycrystalline targets (Ag and Cu) as a function of target temperature are described. Line emission from excited atoms sputtered by argon ions of 8 keV energy was measured. The sputtering yield of the semiconducting material in most cases depends strongly on the target temperature due to the competition of two opposite processes: amorphization under ionic bombardment and thermal restoration of the surface layer. Therefore, the sputtering yield of the Ge target as a function of the temperature was independently measured. The data concerning the sputtering of metals were taken from the literature. The efficiency of photon emission appeared independent of the variation of the target temperature for both types of material.

1. The measurement of the relative variation of the sputtering yield of Ge as a function of the target temperature

The Ge target was a cylinder 10 mm in diameter and 1.2 mm in thickness. The surface of the target was etched by means of a special mixture which consisted of 100 ml HNO_3 and 50 ml HF. The plane (111) was bombarded by an Ar^+ ion beam of density 50 ± 5 μA/cm^2. The ion beam was focused on the target at an angle of 60° with respect to the target normal. The light emission was observed in the plane of incidence perpendicularly to the ion beam. The temperature of the target was changed within the 200–420°C range. The apparatus and experimental techniques were described in detail in the previous paper [3]. The variation of the sputtering yield of Ge as a function of the target temperature is presented in Fig. 1. In the temperature range 200–420°C a considerable increase of the sputtering yield with increasing temperature is observed. This increase is due to the change of loss of ion energy in a solid and decrease of the binding energy of atoms on the perturbed surface [1, 2, 3].

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The plane (100) of single crystals of Ag and Cu was bombarded by argon ions at an angle of 60° with respect to the target normal. According to earlier measurements [4, 5] the sputtering yield for this plane varies no more than 6% in the temperature range from 200°C to 420°C.

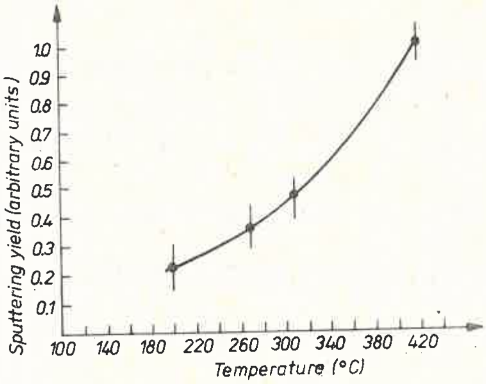

Fig. 1. The sputtering yield of Ge as a function of the target temperature

2. The measurement of photon emission from bombared surfaces as a function of the target temperature

Like the sputtering yield the measurement of photon emission from Ge, Ag and Cu targets was performed at the energy of 8 keV of argon ions. The intensity of selected spectral lines related to atoms sputtered from the surface in the range of temperatures from 200°C to 420°C was registered. Prior to the selection of lines the total spectra were photographed on II AO Kodak plates using a quartz spectrograph. Spectral lines useful for the measurements and interference filters used to select these lines are listed in Table I together.

TABLE I

Target	Wavelength of line (nm)	Spectral properties of the filter	
		Wavelength of transmission	Halfwidth (nm)
Ge	303.9	300	10
Cu	327.3 ; 324.7	325	13
Ag	328.0	325	13

Photometric measurements were realized with a narrow-band interference filters (type DIF of Carl Zeiss Jena) and photomultiplier (type K14FQS 50 of the same manufacturer) followed by a direct-current amplifier, voltage-frequency converter, pulse counter and printer system. From 36 to 48 displays were assumed as a basis to compute an average value of the intensity of line at fixed temperature of the target. All experimental results were normalized to the point which corresponds to the most elevated temperature for each target separately. The results of measurements of photon emission as a function of target temperature are presented in Fig. 2a, 2b, 2c. The plots obtained by minimal square deviations show clearly that photon emission remained constant within the limits of experimental error in the whole considered range of temperatures. A similar result for a GaAs

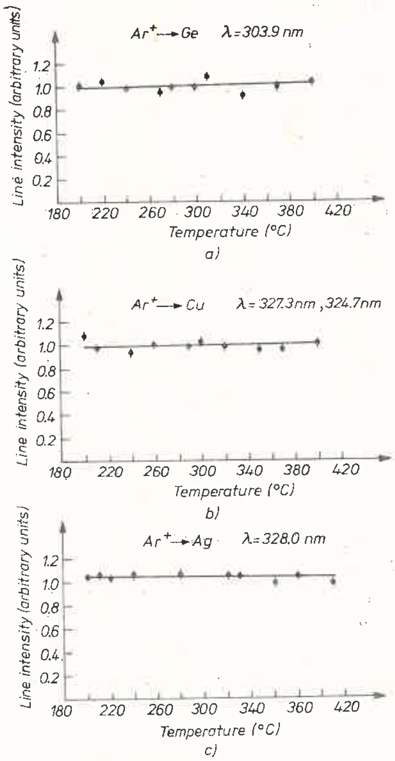

Fig. 2. The intensities of spectral lines of Ge, Cu and Ag as a function of the target temperature

target bombarded by Ar^+ ions of 8 keV energy was presented in the previous paper [3]. Thus independently of the fact, that the sputtering yield is increasing considerably like for Ge or GaAs targets or remains constant at varying temperature like for Cu and Ag targets, the photon emission from sputtered atoms maintains at fixed level.

3. Conclusions

The growth of sputtering yield at elevated temperatures is due to an increase of the number of low-energy sputtered atoms [6, 7]. Their energy contains between a few eV and a few hundred eV. The way of deposition of energy and transportation of energy inside the solid has essentially no influence on the number of sputtered energetic atoms which move with energies comparable with the energy of primary ions bombarding the surface. If we assume that the excitation of sputtered atoms occurs in binary collisions by promotion of electrons in a quasimolecular system atom-atom than the number of atoms which undergo excitation must be limited to those which participate in energetic collisions. The condition for producing a quasimolecule and promotion of electrons is the distance of closest approach to be smaller than the size of the atom [8]. It means that sputtered excited atoms are rather energetic particles and their abundance does not depend on the processes which cause the variation of the sputtering yield.

The experimental results presented above suggest the promotion of electrons in binary atomic collisions as a proper explanation for photon emission from solid surface bombarded by the ions of keV range of energy. The present result also indicates the assumption that the photon emission and the sputtering yield are in linear proportion is not a general rule. One must remark that a number of the authors assume such a linear proportion as a foundation of their consideration. Some of them are listed in reference [9].

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