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Institute of Physics, University M. Curie-Sklodowska

E. KRUPA, W. TAŃSKA-KRUPA, K. PYSZNIAK

250 keV Argon Induced X-ray Emission from Metallic Targets

INTRODUCTION

In contrast to relatively large literature on the X-ray emission, induced by protons or helium ions with MeV-range energy very few works have involved that in medium keV energy ion-atom collides [1–7]. Because this problem is important, for example, in ion implantation, we decided to investigate the emitted X-rays, as a tool for studying the processes which appear in these collisions. Here, we present the experiments conducted to examine the relaxation phenomena in ion-atom collision with energy 250 keV. The ion implanter of the Institute of Physics of the M. Curie-Sklodowska University was used to obtain argon ions with defined energy. The experimental apparatus was designed for simultaneous measurements of X-rays and optical emission induced by heavy ion bombardment.

EXPERIMENTAL

The experimental arrangement is shown schematically in Fig. 1. The measuring interaction chamber with Si(Li) detector is connected with the ion implanter, which permits to implant various ions, with the energy 50–300 keV, to different samples. The Ar^+ ions were obtained in the Sidenius type ion source. After momentum analysis the argon ions were accelerated from 35 keV to 250 keV energy. The ion beam may be focussed on the slit of the sample holder (8 mm diameter) with cylindrical and flat electrodes. The sample holder has four places for the different patterns. Each bombarded sample is inclined at 45° to the ion beam and X-ray detector axis. Samples on the mechanical holder are situated in the cylindrical Faraday cup which has two ports: 1) for the entrances ion of beam and 2) for the exit of X-rays emitted from bombarded target. Exit port is covered with a 5 μm mylar foil, which is replaced by a new one in each experimental run, to secure the

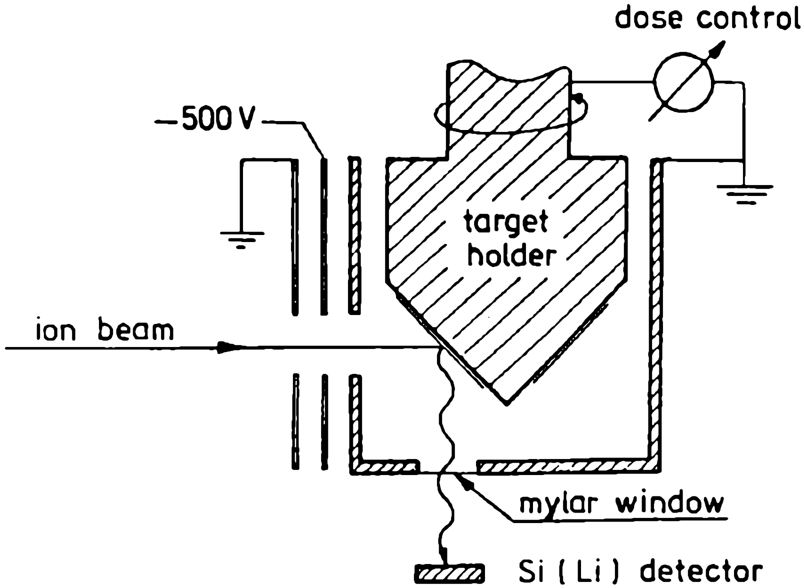

Fig. 1. Schematic diagram of experimental setup

following 25 μm vacuum mylar window from the sputtered ions. Thus the emitted X-rays penetrate two mylar windows and 25 μm detectors beryllium window (6 mm diameter), which is placed in 30 mm distance from the center of the sample. The current and the dose of implanted ions are measured by a current summing integrator. X-rays emitted from the target are registered and energy analyzed by a Si(Li) X-ray detector 20 mm^2×3 mm with a resolution of approximately 240 eV FWHM at 5.9 keV. X-ray spectra are stored in a multichannel analyzer ICA 70.

The tagets used in the experiments were made from spectral purity metallic foils: Zr, Nb, Mo, Rh, Pd, Ag, Sn, W, Pt, Au and Pb with a thickness of 0.25–0.5 mm. As an example, in Fig. 2 is presented the observed L-line X-ray distribution when argon ions incident on the Mo target. The collected charge of implanted argon ions was 6×10^{-4}C. In all cases the count rate was kept below 1.5 kcts/sec. to minimize dead time and pulse pileup.

RESULTS AND DISCUSSION

The X-ray spectra have good pronounced L X-ray lines for Zr, Nb, Mo, Rh, Pd, Ag, Sn and M lines for W, Pt, Au and Pb targets. In Sn and Pb spectra we observed the argon K X-ray line with an intensity lower than that of the target line, however, the dose of implanted argon was about 4 times greater than in targets from Zr to Ag. It should be mentioned, that we observed also a mixed Ar K X-ray line in the Mo target spectrum, especially in the long experiment with this target, i.e. after the high argon ion irradiation. The collected charges of implanted Ar$^+$ ions in our

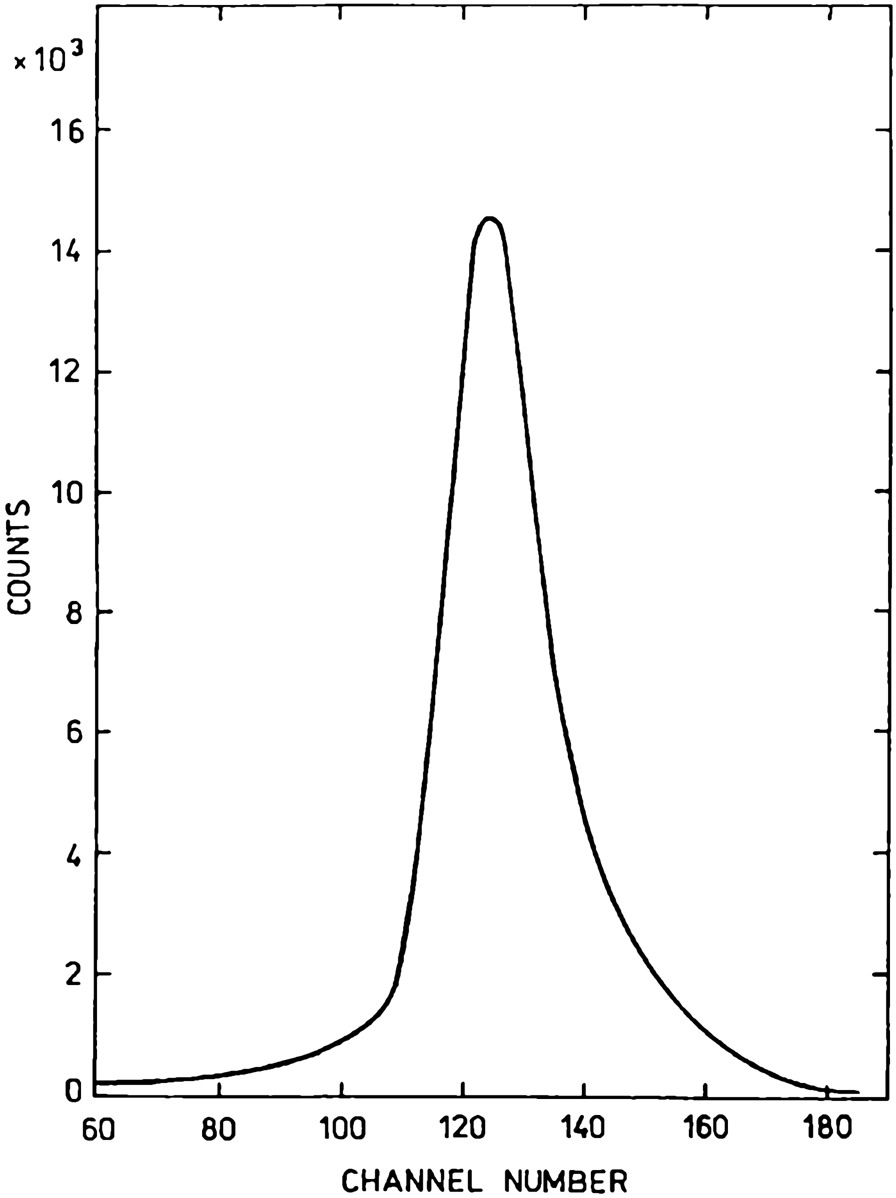

Fig. 2. The molybdenum L X-ray line induced by 250 keV argon ions. The collected charge of implanted ions was 6×10^{-4}C

experiments were: 6×10^{-4}C for Zr, Nb, Mo, Rh, Pd, Ag; 16×10^{-4}C for Pb, Sn and 2×10^{-3}C for W, Pt, Au targets. The contribution of argon K X-rays was lower than 5% in experiments with Zr, Nb, Mo, Rh targets. The precise determination of argon X-ray contribution needs both a high resolution detector and a suitable computer program.

Integrated number of counts below these lines , normalized to the 1 μC ion fluence expressed in counts/μC are shown in Fig. 3. We presented our experimental data in counts normalized to 1 μC ion fluences, since the determination of the absolute X-ray cross-section, in heavy ion collisions, with thick targets is difficult. In addtition we described the experimental conditions during these measurements in experimental section.

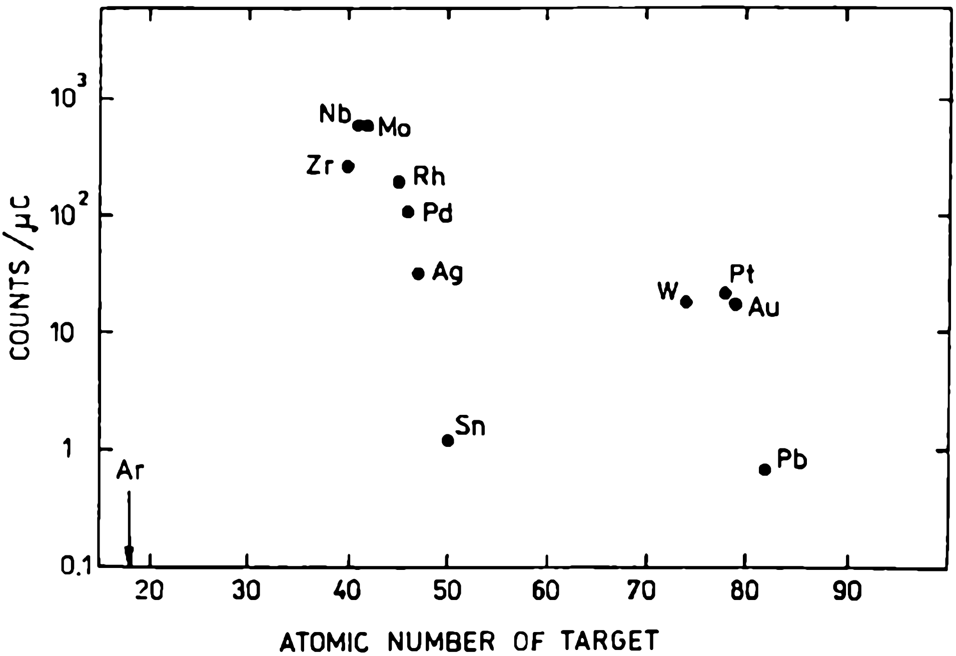

Fig. 3. Yields of X-ray production for 250 keV argon ions as a function of the target atomic number

As can be seen on Fig. 3, the production of X-rays from these targets exhibiths an oscillatory (resonance) structure with peak-valley ratios of almost three orders of magnitude for L-lines (Nb, Mo) and more than one order for M-lines (W, Pt, Au) X-rays. The observed resonance structure may be explained of the "level matching effects" [1,7].

The energy of gold L X-ray equals energy of argon K X-ray and for Pd the difference is about 100 eV. Thus determination of part of Ar X-rays in these cases is impossible. However, because the peak for Ag target is small, which means that ionization of Ag L bands is poor or it is absent. It can conclude that we did not observe an argon projectile X-ray emission when argon ion interacts with target atoms. The observed argon K X-ray were emitted from implanted argon atoms, in all targets.

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