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Anisotropy of L Sub-Shell X-rays in Tungsten at Photon Energies, below and above the L2-Edge

AJAY SHARMA, M.K. TIWARI† and RAJ MITTAL*
Nuclear Science Laboratory, Physics Department, Punjabi University
Patiala-147 002, India
E-mail: rmsingla@yahoo.com

Angular distribution of relative intensities of L X-rays from Tungsten (W) following ionization by photons has been studied at incident photon energies, 10.676 keV (lying between L3 and L2 edges of W) and 17.781 keV. The relative L_ℓ, L_α and L_β intensities has been observed at both the photon energies that have been found to be comparable. Furthermore, the L_λ X-rays were found to show anisotropy more in comparison to other L X-ray groups at both the energies.

Key Words: L X-rays, Anisotropy, Alignment.

INTRODUCTION

For the processes induced by photons, Flugge *et al.*[1] were the first to explore the alignment of inner shell vacancies. Although numerical calculations of vacancy alignment A_{20}, alignment of state j = 3/2, have been performed with different approaches, but some systematic numerical calculations are provided by Berezhko *et al.*[2] and Kleiman and Lohmann[3]. Up to date survey of literature reveals that since eighties the alignment measurements of L-shell X-ray fluorescence (L XRF) cross-sections following photo-ionization in some rare earth and high Z elements are available from the work of seven different groups[4]. The experimental investigations of photon induced L3 vacancy alignment at and near threshold were quoted fairly higher by Papp and Campbell[5] and Yamaoka *et al.*[6] and the same were quoted just comparable to the calculated ones by Barrea *et al.*[7] and Yamaoka *et al.*[8] in their latest paper. Therefore, keeping this in mind, the angular dependence of L X-rays for W has been measured at photon energy 10.676 keV (lying between L3 and L2 edges of W) and 17.781 keV in the angular range 0° to 120° at intervals of 30° each as detailed here.

EXPERIMENTAL

The measurements have been performed in XRF laboratories of RRCAT, Indore. The schematic layout of experimental arrangement used to investigate the angular distribution of photon induced fluorescent L X-rays is shown in the Fig.1. The experiment was performed using a

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† Synchrotron Utilisation Division, Centre for Advanced Technology, Indore, India.

three dimensional double reflection geometrical setup in which Bremsstrahlung radiation from a CuK X-ray tube with a 3 mm window has been used for excitation of primary exciters. A pellet of As_2O_3 and a metallic foil of Mo were used, in turn, as primary exciters. A symmetrical K X-ray beam at 90° from primary exciter was further used to create L sub-shell vacancies in W (99.9 % pure) of thickness 0.527 mg/cm^2. A Mo collimator with a 10 mm window was used in between exciter and W target to collimate the K X-ray beam. A Peltier cooled detector [10 mm^2, Be window thickness 0.5 μm] with FWHM *ca.* 240 eV was in vertical configuration to detect the L X-rays emitted from the experimental target *i.e.*, in a plane perpendicular to the plane formed by the tube, primary exciter and experimental target. The angle scanned by the detector was measured with respect to the direction of the electric vector of the exciting primary X-ray beam. The detector in the direction of the electric vector corresponds to 0° angle.

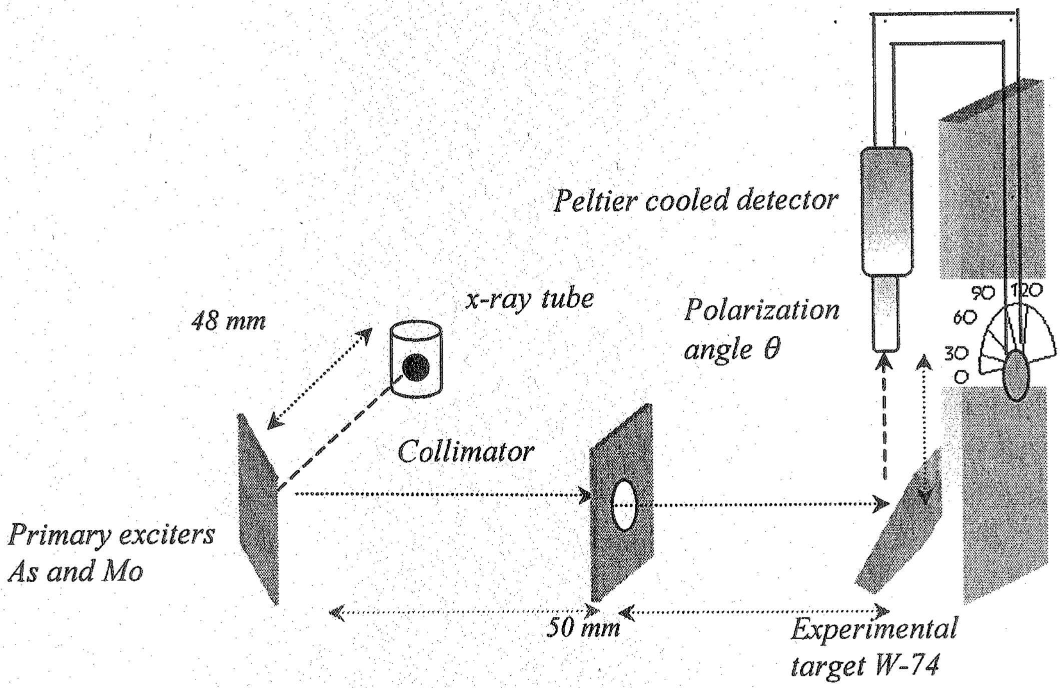

Fig.1. Schematic diagram of experimental set-up used for the measurement

The experiment was run for a sufficient time at each angle to collect counts under the L_ℓ peak within 5% statistical uncertainty. The obtained statistical uncertainty was *ca.* 5% with Mo and *ca.* 2% with As_2O_3 as exciter.

The counts under the various L X-ray peaks (ℓ, α, β and γ) were collected at each angle after a proper background subtraction with multipeak Gaussian fits. The collected counts were manipulated as under:

Solid angle correction

Since, the data was obtained at different angles varying the position of the detector from 0°-120° and keeping the W target fixed. Therefore, the effective area of experimental target W seen by the detector at each angle varied, it was least at 0° and maximum at 90°. Therefore, accordingly solid angle corrections were applied.

Correction for L X-ray contribution due to Bremsstrahlung radiation scattered from primary exciters

To find the Bremsstrahlung radiation scattered from the exciter and reaching at experimental target, the scattered radiation were recorded by placing the detector at the position of tungsten target. As clear from primary scattered spectra (Fig. 2), a lot of Bremsstrahlung is reaching at the experimental target and its spread in energy from 10.3-35.0 keV contributes to the recorded W L X-rays at 10.676 and 17.781 keV. Thus, the spectrum of W was not purely due to 10.676 or 17.781 keV excitations but it included the L X-rays due to the scattered Bremsstrahlung spread at energies > 10.3 keV. To make evaluations for single energy photon excitations, the Bremsstrahlung correction has been applied.

Coster-Kronig correction

In MoK X-ray excitations at energy above L3 threshold of W, the resulted L3 vacancies also included the vacancies transferred from L1 and L2 sub-shells due to C-K transitions. The shifting of isotropic vacancies led to the contamination of L3 vacancies. A correction, (Corr.), ratio of L3 ionization probability to L3 hole production probability, $Corr. = \frac{\sigma_3}{\sigma_3 + \sigma_2 f_{23} + \sigma_1 (f_{13} + f_{12} f_{23})}$, was applied to the data corrected at the previous step. Here σ_i's are sub-shell ionization cross-sections and f_{ij}'s are the intra sub-shell transition probabilities known as Coster-Kronig transition probabilities.

RESULTS AND DISCUSSION

The recent published paper of Barrea *et al.*[7] reflects that the Schematic diagram of co-ordinate system (x,y,z) of present experimental set up (Fig. 1) is very much similar to their dedicated instrumentation designed for anisotropic distribution measurements. With an incident photon oriented along z-axis and the emitted X-rays in the xy plane, it interprets the angle variation as variation of azimuthal angle ϕ with the x-axis, keeping the polar angle θ, between incoming photon and the outgoing photon, fixed at 90°. Since $L\ell$ X-rays comprising the X-ray lines originating from L1 and L2 sub-shells are isotropic thus for anisotropy studies only Lg (g = ℓ, α and β) are considered.

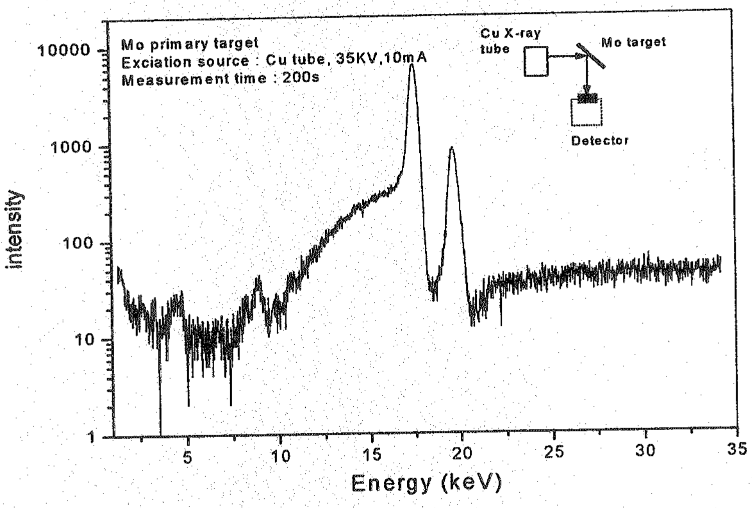

Fig. 2. The fluorescence spectrum of a primary target Mo, excited from Bremsstrahlung radiation of Cu X-ray tube at 35 KV, 10 mA with detector at the position of W target

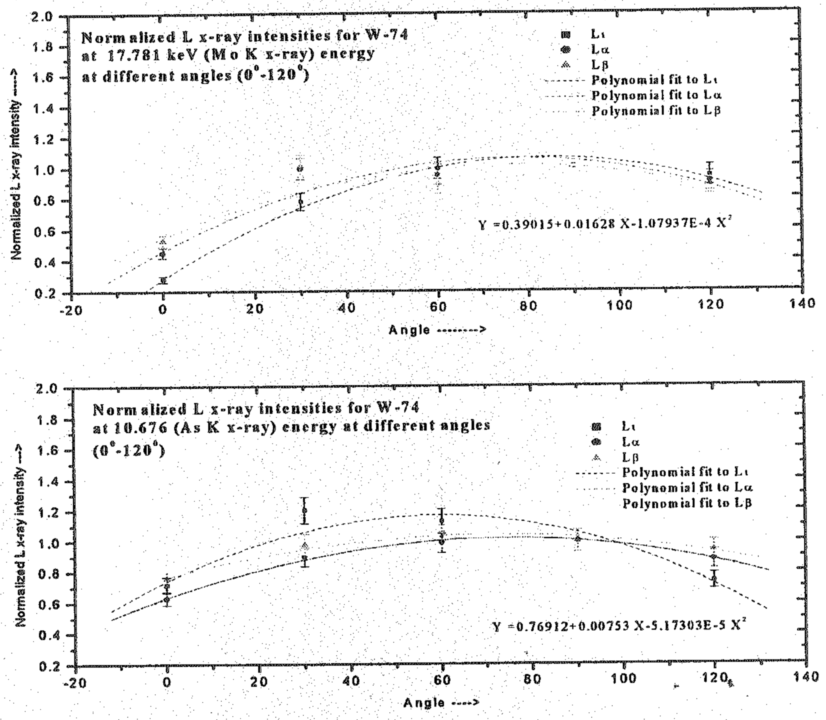

Fig. 3. Plots of Normalized L X-ray intensities vs. the angle for W

Moreover, for both 10.676 and 17.781 keV excitations, the final corrected counts correspond to a similar experimental set up [from parent source to the production of L X-rays in W]. Thus, N_{Lg} (ϕ) (g = ℓ, α and β) sub-shell X-ray counts just depend upon detector efficiency and angle of observation (ϕ). In the W L X-ray energy span (7.384-12.051 keV), the detector efficiency is almost constant. Thus, to make final data independent of detector efficiency, the corrected counts at each angle under each peak were normalized with the corresponding counts at 90°. The obtained relative counts are shown as plots (Fig. 3). To accommodate the statistical errors in counts, a uniform error 7% has been added to each data value.

The present results show an angle dependence of relative L_ℓ, L_α and L_β intensities at both the photon energies and it has been found to be comparable. L_ℓ X-rays were found to show more variation in comparison to other L X-ray groups.

REFERENCES

1. S. Flugge, W. Mehlhorn and V. Schmidt, *Phys. Rev. Lett.*, **29**, 7 (1972).
2. E.G. Berezhko, N.M. Kabachnik and V.S. Rostovsky, *J. Phys. B.*, **11**, 1749 (1978.)
3. U. Kleiman and B. Lohmann, *J. Elect. Spectro. Rel. Phen.*, **131**, 29 (2003).
4. A. Sharma, M. Singh and R. Mittal, *Pramana*, **66**, 1111 (2006).
5. T. Papp and J.L. Campbell, *J. Phys. B.*, **25**, 3765 (1992).
6. H. Yamaoka, M. Oura, K. Takahiro, N. Takeshima, K. Kawatsura, M. Mizumaki, U. Kleiman, N.M. Kabachnik and T. Mukoyama, *Phys. Rev. A.*, **65** 062713-1 (2002).
7. R.A. Barrea, C.A. Perez, T.S. Plivelic, E.V. Bonzi and H.J. Sanchez, *J. Phys. B.*, **38**, 839 (2005).
8. H. Yamaoka, M. Oura, K. Takahiro, K. Kawatsura, S. Ito, M. Mizumaki, H. Oohashi, Y. Ito and T. Mukoyama, *J. Phys. B.*, **39**, 2747 (2006).