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MEASUREMENT OF ABSORPTION COEFFICIENT OF NICKEL AROUND THE K-EDGE USING 8271.2-8849.4eV SYNCHROTRON RADIATION BASED X-RAY ABSORPTION STUDY.

BUNTY RANI ROY[1*] , PARASMANI RAJPUT[2],A. S. NAGESWARA RAO[1]
[1]Dept. of Physics, Kakatiya University, Warangal, Telangana state, India.
[2]Atomic & Molecular Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India.
*E mail: buntyroy.physics@gmail.com

Bunty Rani Roy

ABSTRACT

The work presents the X-ray absorption fine structure (XAFS) technique for measuring the absorption coefficient of Nickel metal foil in the X-ray energy range of 8271.2-8849.4 eV using scanning XAFS beam line (BL-09) at Indus-2 synchrotron radiation source facility, Raja Ramanna Centre for Advanced Technology (RRCAT) at Indore, India. The result represents the X-ray absorption data for 0.0125 mm thick Ni metal foil in the XAFS region of Ni K-edge. However, the results are compared to theoretical values using X-COM. There is a maximum deviation which is found near the theoretical K-edge jump. Oscillatory structure appears just above the observed absorption edge i.e., 8349.1 eV and is confined to ~ 350 eV above the edge. It is also seen that oscillatory structure reduces to a smooth line as we move away from the observed edge.

Keywords: absorption coefficients, synchrotron radiation, XAFS.

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INTRODUCTION

Study of interaction of low energy photons are of significant important both from the point of view of basic research in atomic physics and in applied physics [1]. Accurate data on photon absorption coefficient in several materials is needed in solving various problems in many fields such as nuclear diagnostics, nuclear medicine, radiation protection, radiation dosimetry, shielding, security screening, research and development etc.

However X-ray absorption coefficients [μ] describe indeed the reduction in intensity of radiation when it passes through any medium. The development of theoretical and experimental investigations of the interaction of X-rays with atoms has been a continuing effort [2]. Since many years significant photon attenuation measurements, calculations and compilations in materials have been published [3-12]. There has been also renewed interest in the measurement of photon interaction cross section at low energies especially energies close to the absorption edges of elements[13-22], and in many cases it was the extrapolation method which was used to measure attenuation value near the edge. The discrepancies and envelop of uncertainity of available μ data have been examined from time to time, including the effect of molecular and ionic chemical binding, particularly in the vicinity of absorption edges [23].

The availability of modern Synchrotron radiation (SR) helps to reach many field of research (24). XAFS spectroscopy has developed the growth of SR research. μ is the basic physical quantity that is measured in XAFS and which describes how strong X-rays are absorbed as a function of energy. A typical example of the material based on SR is the work of Chantler et al., [25]. A number of measurements have been carried out over the years to determine absorption coefficients using SR [26-30].

A search of literature has shown that in the previous measurements there are fine gaps which can be measured in lower energy range exactly in the vicinity of absorption edge. So it is worthwhile to undertake absorption measurements to cover some of the existing gaps exactly near the absorption edge jump.

In the present study absorption coefficient is evaluated for Ni element using synchrotron radiation in the energy range 8271.2-8849.4 eV, and compared with X-COM theoretical values[8].

II. Experimental Technique

The schematic layout of scanning XAFS beam line (BL-09) is shown in Fig.1. The Beam line is built around bending magnet source of Indus-2 and it operates in the energy range of 4-25 keV using Si (111) doubled crystal monochromator (DCM). The BL-optics consists of two Rh/Pt coated meridional cylindrical mirrors. The pre-mirror is used for collimating the beam and post-mirror is used for focusing the beam in vertical plane at sample position. The collimated beam has been monochromatized by Si (111) based DCM. The second crystal of DCM is a saggital cylindrical with variable radius of curvature for focusing the beam horizontally.

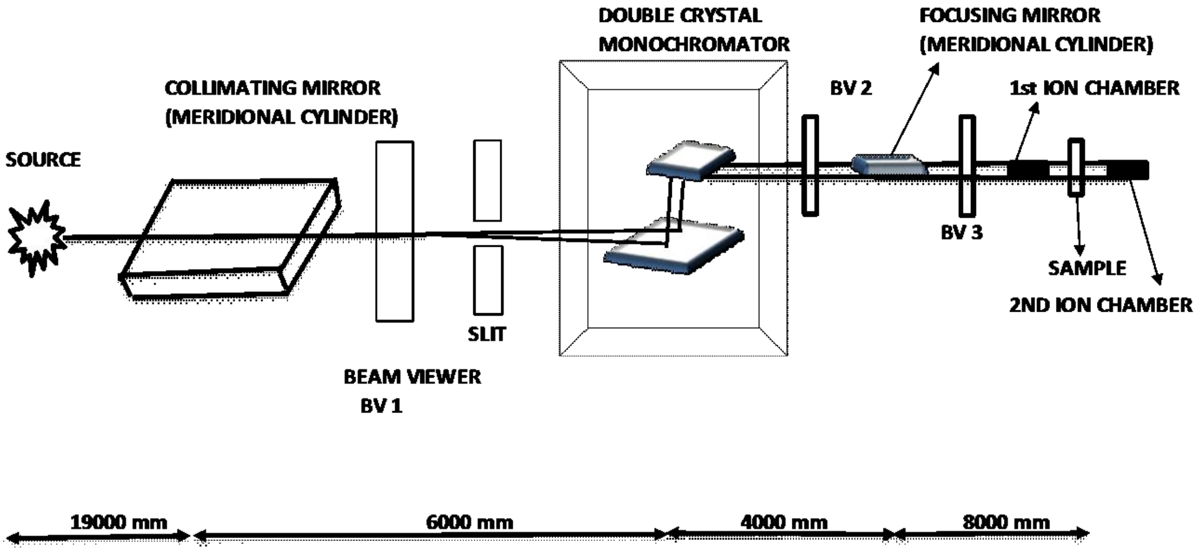

Fig.1 Schematic layout of BL-09, RRCAT, Indore, India.

Three ionization chambers (IC) have been used for data collection in transmission mode. First IC (IC-1) measures incident flux (I_o), second IC (IC-2) measures transmitted flux (I_t) and third IC (IC-3) measures the standard reference spectra over the energy range. The sample was placed between IC-1 and IC-2. Appropriate gas pressure and mixture of N_2 and Ar gases have been chosen to improve signal to noise ratio. From these intensities the absorption coefficient of the sample is determined as a function of energy. The experimental absorption coefficient μ (1/cm) is obtained by using equation

$$\mu = \frac{1}{t} \ln \left(\frac{Io}{I_t}\right)$$

Where I_0/I_t is the transmission fraction, “t” thickness of absorbing material

The Ni foil sample of 12.5 micron was supplied by Good Fellow, quoted purity of 99.99%

III. Results and Discussion

The theoretical K-edge of Ni is taken as 8333.0 eV from XCOM [8]. Experimental energy step of 0.5 eV is taken exactly near the K-edge and pre-edge and increased by ~2eV and 5eV as we move away from the theoretical K-edge. The XAFS spectra of the sample were recorded in the energy range of 8271.2 – 8849.4 eV as shown in Fig. 2.

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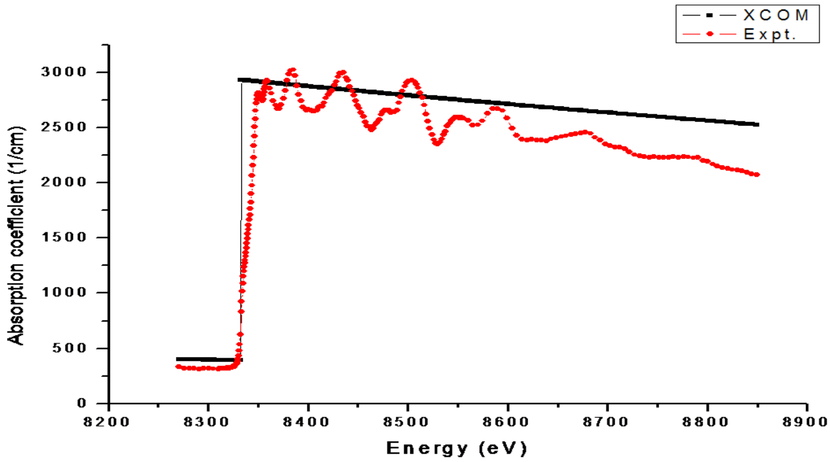

Fig.2. The XAFS spectra of 0.0125 mm thick Ni metal foil as a function of energy (eV) Vs absorption coefficient μ

From the XAFS spectra, it has been observed that experimental values of μ are less than the theoretical values till the pre-edge i.e, 8271.2 eV through 8329.5 eV and the percentage of deviation varies from 21.1 % through 2.5 %. From 8330.0 eV through 8332.0eV i.e., very near to the pre-edge experimental values are greater than the theoretical values and the % of deviation varies from 2.9 % to 58.5%. More important and interesting point is that, the oscillatory nature is not observed near the pre-edge region (8271.2- 8332.0eV).

In Fig. 2, exactly near the K-edge at 8333.0 eV, experimental value is less than theoretical value and the percentage of deviation is very high i.e, 71.5 %. Above K-edge i.e, 8333.5 eV through 8349.1 eV, the percentage of deviation decreases from 68.3 % to 4.3% and the experimental values are less than the theoretical values. Experimentally observed oscillatory structure starts just after 8349.1 eV. Peaks occur in the XAFS spectrum due to interference phenomenon of atomic photo electron wave and scattered photoelectron wave from neighbouring atoms. The observed peaks are at 8349.6eV, 8358.9eV, 8384.9 V, 8435.9 eV, and 8504.5 eV,8584.9 eV. It is Observed that oscillations are confined to ≈350 eV (8349.6eV to 8678.0eV) above the observed edge with absorption coefficients varying from ≈15.2 % to 0.2% around the theoretical value. As we move away from the K-edge (8682.9-8849.4 eV) the oscillatory nature reduces to a smooth line and the deviation between theoretical and experimental value increases i.e., 7.5% to 18 %. This indicates that the edge effects are probably present along with the environmental effects due to interference phenomenon. They exhibit oscillatory nature, resulting in positive and negative deviation of μ/ρ values.

IV. Conclusion

Using radioactive sources the oscillatory structures near the absorption edge are currently ignored for various applications [31]. Experimental capabilities, including synchrotron light source, advanced technique, new detectors with better resolution and efficiencies provide more accurate measured value of "μ" to test and understand the theoretical advances.

Though the work had been carried out by Chantler et al [25-29] and group near the absorption edge and which has encouraged our group to make the measurements at a very fine step of 0.5 eV exactly near the K-edge jump and where we had found a maximum deviation. However, much work in this direction is necessary to confirm these observations. Thus the study of the photon interaction at and around absorption edge is very important both from fundamental and applications point of view.

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