Measurement of X-ray absorption coefficient of Niobium using the Synchrotron radiation source

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Abstract — The X-ray absorption coefficient of niobium in the energy range 18.5-19.7 keV around the k-edge is measured using scanning EXAFS synchrotron radiation source. The discrepancies between the measured absorption coefficients and alternative theoretical predictions are discussed.

Keywords — Absorption coefficient, Synchrotron Radiation, EXAFS

I. INTRODUCTION

The motive of the present work is to measure the absorption of Niobium which fulfill the requirements for interaction study in the increasing applications of low energy photons which is also important in basic views of both researches that is atomic physics and in applied physics [1]. The extent of absorption depends on the energy of photon taken by the material. The measurements of absorption values have been reported on the various types of materials such as elements, compounds, tissue equivalent compounds, alloys, heavy metal oxide borate glasses, soils and building materials, etc., [2-11].

II. RELATED WORK

X-ray attenuation measurements near the absorption edge using radioactive source were already reported are very limited and in many cases it was the extrapolation method which was used as attenuation values exactly near the edge jump [12, 13]. To overcome this extrapolation method one need to go for a continuous energy source. Synchrotron radiation (SR) source is one such source which can be tuned near the edge-jump, so that one can also go for accurate measurements near the edge-jump. So, it is worthwhile to undertake absorption measurements to cover some of the existing gaps around the absorption edge and this coefficient is a basic parameter for many studies [14]. A Large number of measurements have been reported over the years to determine attenuation coefficients using synchrotron radiation [15-19]. This encouraged taking up a systematic work in the present study where experimental absorption coefficient is evaluated for Niobium (Nb) element using synchrotron radiation which remains one of the most useful material. The measured values are compared with X-COM Which was developed by [20] and FFAST [21] theoretical values.

III. MATERIALS AND METHODS

The element used for the measurement of absorption coefficient data is a pure Nb metal which was obtained from Good Fellow, England, quoted purity of 99.9%. A method for the determination of the absorption coefficient (μ) is using synchrotron radiation, which operates in the energy range of 4-25 keV using Si(111) doubled crystal monochromator (DCM) have been discussed in [22]. The observed values were compared with theoretical values using XCOM and FFAST as shown in Figure 1. The X-ray energy absorption fine structure (XAFS) spectra of the sample were recorded in the energy range from 18.5 to 19.7 keV, and the absorption coefficient of the sample is determined as a function of energy.

Figure 1. The XAFS spectra of experimental and theoretical absorption coefficient (1/cm) for photon energies (keV) of Niobium metal
IV. RESULTS AND DISCUSSION

The results include the observations of the absorption coefficient of Nb elemental foil using Synchrotron radiation source from energy 18.5 to 19.7 keV. The measured values are compared with theoretical values predicted using XCOM method. The measurements were done at an energy step of 0.0003 keV. From the graph, in Figure 1, it is observed that near the pre-edge region, i.e., from 18.91 to 19.95 keV the measured values are less than the theoretical values predicted using XCOM and the deviation is 98%. Interesting point is to be noted that there is no oscillatory nature found in the pre-edge region, which had covered an energy range of 0.045 keV in the present work. Exactly near the theoretical k-edge jump i.e., 18.99 keV, the deviation is 46%. One can see from the Figure 2 that the experimental k-edge jump energy is 19.009 keV. Where the deviation obtained is decreased by 1% i.e., 45%. The oscillatory nature is seen near the k-edge jump with absorption coefficient varying from 69 - 45%. As we are moving away from the observed k-edge jump the oscillatory nature is reduced to smooth line which covered an energy range from 19.28 to 19.68 keV. The present work had covered a total energy of less than 1 keV where a fine energy step of 0.0003 keV is used at regular interval to carry the absorption measurements. The oscillatory nature which is seen near the k-edge jump is due to interference phenomenon resulting in positive and negative deviation of μ values. Peaks in the XAFS spectrum occur due to interference phenomenon of atomic photo electron wave and scattered photo electron wave from neighboring atoms. The measured values are also compared with FFAST theoretical values and the observation does not find much difference when compared with XCOM theoretical readings. The % discrepancy vs energy graph of present work with XCOM and FFAST is shown in Figure 2.

V. CONCLUSION AND FUTURE SCOPE

Using a continuous source (SR) the present work is carried with a very fine energy step of 0.0003 keV exactly near the k-edge jump where the measured values are deviating from theoretical values to a large extent. Hence their need of further experimental measurements to overcome the deviations.

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Fig. 2. Comparison between theoretical measurements and the present work of niobium
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