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X-ışını Enerjileri Kullanılarak $MgB_{2-x}SiC_x$ (%5) Süperiletken için Kütle Soğurma Katsayıları ve Etkin Atom Numarası Ölçümü

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Anahtar Kelimeler
X- Işınları
Kütle Soğurma Katsayısı
Etkin Atomik Numarası

Özet: Süper iletken kütle $MgB_{2-x}SiC_x$ (% 5) kütle soğurma katsayıları (% 5) 14,16 - 36,37 keV enerji aralığında ölçülerek hesaplanmış ve etkili atom sayıları tahmin edilmiştir. Belirlenen enerjileri, 241-Am'in gama ışını fotonları ile ışınlanmış sekonder hedefler kullanılarak elde edildi. X ışınları 5.9 keV'de 150 eV çözünürlüğe sahip Canberra Ultra-LEGe dedektörü kullanılarak sayıldı. Sonuçlar teorik olarak hesaplanan değerlerle karşılaştırıldı ve ortalama bir deneysel hata ile uyumlu olduğu tespit edildi.

Measurement of Mass Attenuation Coefficients and Effective Atomic Numbers for $MgB_{2-x}SiC_x$ (%5) Superconductor Using X- Ray Energies

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Keywords
X –Rays
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Coefficient Effective
Atomic number

Abstract: The mass attenuation coefficients for superconducting bulk $MgB_{2-x}SiC_x$ (5%) were measured in the energy range 14,16 - 36,37 keV and effective atomic numbers were calculated. The energies were obtained by using secondary targets that were irradiated with gamma-ray photons of 241-Am. The X-rays were counted by using a Canberra Ultra-LEGe detector with a resolution of 150 eV at 5.9 keV. The results were compared with theoretical calculated values and fairly good agreement was found between them within an average experimental error.

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1. Introduction

The electrical resistivity of many metals and alloys drops suddenly to zero value when the specimen is cooled down to a critical temperature which the resistant of the material suddenly drop to the zero, the phenomena is called superconductivity, was observed first by Kamerlingh Onness in Leiden in 1911,cthree years after he first liquefied helium. After learned to superconductor's structure many superconductor alloys, compounds were studied by researchers. One of this superconductor compound is MgB_2 [1-6].

The boron atoms in MgB_2 form graphite like sheets separated by hexagonal magnesium atom layers. This compound is a mixed bonded solid: the bonding between boron atoms is covalent, between boron and magnesium atoms ionic and between magnesium atoms metallic [7]. Recently $MgB_{2-x}SiC_x$ type superconductor was investigated and found that SiC doped are increased of flux for MgB_2 superconductor [8-10]

The mass attenuation coefficients are a measure of the average number of interactions that occur between incident photons and matter mass per unit area. They are related to the atomic number of element and the photon energy. In composite materials like alloys, for photon interactions a single atomic number cannot represent the atomic number uniquely across the entire energy region because of the effective number being related to the density and atomic number of an element. The partial interaction cross-sections have different elemental number dependence. This number for composite materials is called the effective atomic number and also it varies with energy [11].

There are many studies like Singh *et al* [12] measured gamma-ray attenuation coefficients in bismuth borate glasses using the narrow transmission method. Akkurt *et al* [13] made a study on *Z* dependence of partial and total mass attenuation coefficients with the help of XCOM. Materna *et al* [14] performed near *K*-edge measurement of x-ray attenuation coefficients of bismuth and uranium using a tuneable hard X-ray source based on the linear electron accelerator. Moreover, there are many studies on the mass attenuation coefficients, ranging from determining the energy and composition dependences of the mass attenuation coefficient of building materials to determining the mass attenuation coefficients of Earth, Moon and Mars samples [15–23].

Effective atomic numbers and electron densities have been calculated for some investigators whose studies about amino acids and sugars [24–27] and polypyrrole [28] using total attenuation coefficients. El-Kateb *et al* [29] have measured the atomic cross sections and effective atomic numbers for some alloys. For some biological compounds containing H, C, N and O, Manjunathaguru and Umes [30, 31] have measured the total cross sections, effective atomic numbers and electron densities in the energy range 6.4–1330 keV. In addition to these studies, many researchers [32–42] performed a number of studies on the electron densities and effective atom and effective atomic numbers of different materials.

In this study the mass attenuation coefficients and effective atomic number for MgB_2 doped SiC (5%) was studied.

2. Theoretical information

Mass attenuation coefficients for the superconducting materials and energies are determined by the transmission for collimated monoenergetic beam. If a material of thickness x (cm) is placed in the path of beam of gamma or X-ray radiations, the intensity of beam will be attenuated according to Beer-Lambert' s law:

$$I = I_0 e^{-\mu x} \tag{1}$$

where μ (cm^{-1}) is linear attenuation coefficient of the material and I_0 and I are the non-attenuated and attenuated photon intensity. A coefficient, accurately characterizing a given material, is the density-independent mass attenuation coefficient μ/ρ ($cm^2 g^{-1}$).

$$I = I_0 e^{-(\mu/\rho)\rho x} = I_0 e^{-(\mu/\rho)d} \tag{2}$$

Where d is the mass per unit area (g/cm^2)

The mass attenuation coefficient, μ/ρ , for a compound or a mixture is given by:

$$\frac{\mu}{\rho} = \sum_i w_i \left(\frac{\mu}{\rho}\right) \tag{3}$$

where ρ is density of mass of the target, and, w_i and $(\mu/\rho)_i$ are the weight fraction and mass attenuation coefficient, respectively, of the constituent element i. For a chemical compound, the fraction by weight is given by:

$$w_i = \frac{niAi}{\sum_i niAi} \tag{4}$$

where *Ai* is the atomic weight of the ith element and ni is the number of formula units.

Theoretical values for the mass attenuation coefficients of $MgB_{2-x}SiC_x$ alloy was calculated by program XCOM and photon cross-section database [44] according to the mixture rule:

$$\sigma_{t,m} = 1/N(\mu/\rho)_c \sum_i (n_i Ai) \tag{5}$$

where N ia the Avogadro number.

Total atomic cross-section (σ t,a) can be easily determined by using equation (5) as

$$\sigma t,a = \sigma t,m \Big/ \sum_i n_i = 1/N \sum_i f_i Ai(\mu/\rho)_i \tag{6}$$

where fi= ni/Σini is the fractional abundance of element i with regard to number of atoms.

The total electronic cross-section (σt,el) for the individual elements is expressed by the following formula:

$$\sigma t,el = 1/N \sum_i f_i Ai / Z_i (\mu/\rho) \tag{7}$$

where *Zi* is the atomic number of the *i*th element in a molecule.

The total atomic and electronic cross-sections are related to the effective atomic number (*Z*eff) through the following relation [4]:

$$Z_{\text{eff}} = \frac{\sigma t,a}{\sigma t,el} \tag{8}$$

The electron density *N*el (number of electrons per unit mass) can be derived by using Equations (2) and (7)

3. Experimental procedure

According to general formula $MgB_{2-x}SiC_x$ (x=0.05), MgB2 and SiC-doped bulk superconductors were prepared by the standard ceramic processing. The mixtures of the corresponding powders were sintered at 750 0C for 0.5 h under pressure of 8 bar Argon.

The schematic arrangement of experimental set up was shown that previous paper [43].

The X-rays transmitted from the absorber were detected using a Canberra Ultra-LEGe detector with an active area of 30 mm^2, a thickness of 5 mm, a Be window thickness of 0.4µm and an energy resolution of 0.15 keV at 5.96 keV. The output from the preamplifier, with pulse pile-up rejection capability, was fed to a multi-channel analyser interfaced with a personal computer provided with suitable software for data acquisition and a peak analysis program.

The signal-to-noise ratios of the spectra of the samples were in an acceptable region for a good-quality sample. A very narrow collimator is ideal to avoid scattered radiations reaching the detector. However, the narrow collimator reduces the count rate and adversely affects the counting statistics. To reduce the error due to poor statistics, the collimator has to be wider. Obviously, one has to arrive at an optimum value between these two opposite trends. The incident and transmitted intensities are determined by integrating the counts in the channels under a photo peak. While determining the transmitted intensity, one has to avoid counting photon that have suffered small angle and multiple scattering but yet reach the detector. In an experiment like this, these important parameters have to be judiciously selected to arrive at accurate values for attenuation coefficients [45].

The dead time of the multichannel analyser is a combination of the rise time of the pulse, the conversion time in the analogue-to-digital converter and the data processing time. There was a built-in provision for dead time correction in the multi-channel analyser used in the present measurements. In the present measurements, the percentage dead time correction was always 2–3%.

The thickness of the samples that are suitable for transmission measurements is dictated by counting statistics. The sample thickness has been optimized so that multiple scattering effects are corrected for in the present experiment. Also, in the present measurements, the intensity of bremsstrahlung secondary photons would be very low. A detector of high resolution as well as a thin absorber was used; so the effects of photon build-up are expected to be negligible in the present measurements. In addition, the pulse pile-up effects were kept at a minimum by selecting an optimal count rate [43].

In this study are investigated that the mass attenuation and the effective atomic number measured for $MgB_{2-x}SiC_x$ superconductor.

4. Results and Discussion

The nominal composition of MgB_2 superconducting powders were prepared by the mixing of magnesium and boron in the stoichiometric ratio 1:2 using the standard ceramic processing. SiC-doped MgB_2 powders were well mixed for 1.5 h with the ratio of %5. The mixtures of the 1 gram powder were pressed into the rectangle pellets form in the size of 10x15 mm under the 10 ton pressure and put in a stainless steel tube under 8 barr argon gas pressures and sintered at 650 ^{0}C for 1.5 h. The stainless steel tube was removed from the furnace to air cool to room temperature.

In order to improve the homogeneity of reacted powders, the pellets were crushed into small pieces and ground using a mortar machine for 1.5 hours. Finally, the fine powders were pressed into the rectangle pellets form in the size of 10x15 mm under the 10 ton pressure and sintered at 750 ^{0}C for 0.5 hours under 8 bar argon gas pressures in same conditions.

The phase and crystal structure of all the samples was obtained from x-ray diffraction (XRD) patterns using a Rigaku D/Max-III diffract meter with Cu$K\alpha$ radiation. Densities of samples were measurement using Archimedes method.

The x-ray diffraction (XRD) patterns of MgB_{2-x} (SiC) $_x$ (x= 5%,) is shown in figure1.According to Fig.1.when the content of SiC increases some unknown peaks appear. This peaks belong to SiC and MgO.

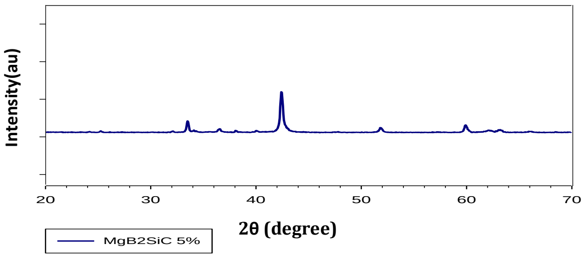

Figure 1. XRD pattern of MgB_{2-x} (SiC) $_x$ (x=5 %) sample

In Table 1, the experimental and theoretical mass attenuation coefficients (μ/ρ) for bulk $MgB_{2-x}SiC_x$ superconductors sintered at 8 Ar pressure and a represented at 14.16, 15.77, 15.83, 17.66, 19.27, 21.65, 22.16, 24.94, 25.27, 27.47, 28.48, 30.99, 32.19, and 36.37 keV photon energies. Theoretical values of mass attenuation coefficients have been calcuated by using XCOM computer program. Our results and theoretical values were shown at Table 1. According to values the mass attenuation coefficients decreased with increasing photon energies.

Table 1. Experimental and theoretical values of the mass attenuation coefficients μ/ρ (cm^{2}g^{-1}) for bulk MgB$_{2-x}$SiC$_x$ supercondutors

Energy (keV)	Exp.	Theo.
14.16	4.54	4.43
15.77	3.05	3.25
15.83	3.06	3.22
17.66	2.65	2.36
19.27	1.59	1.85
21.65	1.01	1.35
22.16	1.28	1.27
24.94	0.76	0.94
25.27	0.86	0.91
27.47	0.76	0.74
28.48	0.79	0.68
30.99	0.49	0.56
32.19	0.69	0.52
36.37	0.43	0.41

At the Fig. 2 is shown that experimental values and theoretical values are in good relation each other.

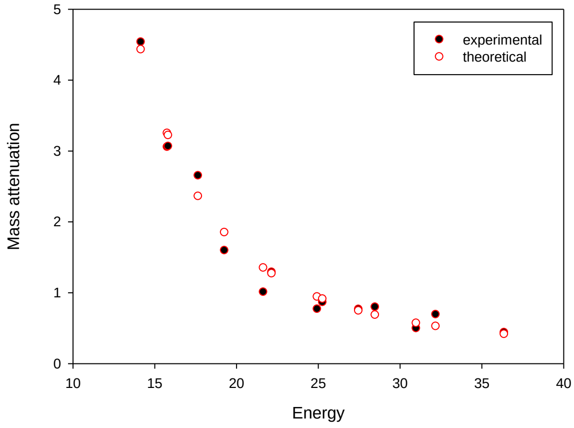

Figure 2. Comparison of theoretical and experimental data of Mass attenuation coefficients

By using experimental and theoretical data of μ/ρ, the effective atomic numbers Z_{eff} were determined from Eq. (8) and the variation of Zeff with photon energy for MgB$_2$-xSiCx superconductors is tabulated in Table 2. These values show that Zeff changes with the photon energy. Theoretical values and our results conform with each other. The errors in the present measurement are estimated to be 8–10% due to the evolution of peak areas (≤ 5%) sample thickness measurements (≈2%) and counting statistics (≤2%).

Table 2. Theoretical and experimental values of Z_{eff} for bulk MgB$_{2-x}$SiC$_x$ supercondutor

Energy (keV)	Theo.	Exp.
14.16	7.4	7.29
15.77	7.4	7.39
15.83	7.4	7.28
17.66	14.95	14.94
19.27	14.90	14.90
21.65	14.89	14.86
22.16	14.85	14.83
24.94	14.80	14.80
25.27	14.74	13.25
27.47	14.60	13.66
28.48	14.48	13.46
30.99	14.27	13. 39
32.19	14.19	14.20
36.37	14.00	13.00

In this paper the mass attenuation coefficients and the effective atomic numbers of MgB$_{2-x}$SiC$_x$ superconductor were estimated at the energy range of 14.16-36.37. The results were compared with the theoretical values and there is qualitative agreement between each other. We have shown that a MgB$_{2-x}$SiC$_x$ superconductor is a good absorber in the above mentioned energy range.

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