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Research Article

Albedo Factor Determination of Some Selected Cu Compounds

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Abstract

Albedo factor parameter has recently come to the fore as a remarkable topic. The albedo factor parameter consists of 3 components: albedo number, albedo dose, and albedo number. With the albedo factor calculation, one of the radiation shielding parameters, the incoming radiation scattering coefficient of the target sample is calculated. In this article, the albedo factors of some copper compounds have been examined. The related investigation of the selected samples has been carried out by using radiation sources and semiconductor detectors. Thereby, the calculated shielding parameters have been plotted as a function of the mean atomic numbers of target samples. Finally, this study shows that the increasing mean atomic number of the selected samples causes decreases in albedo factor parameters of the selected samples.

Keywords: XRF, Albedo Factor, Albedo Number, Albedo Dose, Albedo Energy.

Bazı Seçilmiş Cu Bileşiklerinin Albedo Faktörü Tayini

Öz

Albedo faktör parametresi son zamanlarda dikkat çekici bir konu olarak öne çıkmıştır. Albedo faktör parametresi 3 bileşenden oluşur: albedo sayısı, albedo dozu ve albedo sayısı. Radyasyon kalkanlama parametrelerinden albedo faktör hesaplaması ile hedef numunenin gelen radyasyonu saçma katsayısı hesaplanır. Bu makalede, bazı bakır bileşiklerinin albedo faktörleri incelenmiştir. Seçilen numuneler ile ilgili araştırmalar, radyasyon kaynakları ve yarı iletken dedektörler kullanılarak yapılmıştır. Böylelikle, hesaplanan zırhlama parametreleri, hedef numunelerin ortalama atom numaralarının bir fonksiyonu olarak çizilmiştir. Son olarak, bu çalışma, seçilen numunelerin artan ortalama atom sayısının, seçilen numunelerin albedo faktör parametrelerinde düşüşlere neden olduğunu göstermektedir.

Anahtar Kelimeler: XRF, Albedo Faktör, Albedo Numarası, Albedo Dozu, Albedo Enerjisi.

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1. Introduction

The X-ray fluorescence spectrometer (XRF), which is frequently used by researchers, is a versatile tool that provides non-destructive testing to solve many analytical problems. Energy dispersive x-ray fluorescence spectroscopy has recently been used by many researchers in the analysis of materials containing multiple elements. As such, it stands out that the x-ray fluorescence spectroscopy technique can measure multiple elements simultaneously and allows a simple prediction about materials. Also, this technique is very useful because it is independent of the physical or chemical composition of the elements in sample materials. Using the x-ray fluorescence spectroscopy technique that we have mentioned, it is possible to determine the ratios of Compton and coherently scattered photons from the target sample.

It is appropriate to divide the photon-atom interactions into elastic or inelastic processes depending on the photon energy changes in the collision frame. This separation helps in understanding the emitted soft photons and target recoiling possibilities on scattering phenomena. Thus, the soft photon emitting, and the target recoiling events are all inelastic scattering processes. Also, the inelastic scattering processes are including photoexcitation, Compton scattering, and pair productions events. Different from inelastic scattering events, the elastic photon-atom interactions include scattering from bound electrons (Rayleigh scattering) and nuclear Thomson scattering, Delbrück scattering, and nuclear resonance scattering, respectively.
This essay will concentrate on explaining the elastic and inelastic scattering intensity ratios that namely albedo factors of selected samples. Incidentally, it would be useful to explain that the albedo factor parameter that specifies the photon scattering capability of a material composed of a combination of different elements or a pure element. The albedo factor, which is only one of the shielding parameters, consists of 3 different components that namely, the albedo number, albedo dose, and albedo energy.

The backscattering measurement and the albedo factor parameter studies were carried out by many researchers. Akkuş (2020) have studied the albedo factor parameters of various samples that the mean atomic number varies $9.743 \leq \bar{Z} \leq 83.00$. Prepared samples were irradiated by using 59.54 keV gamma-photos that emitted from ^{241}Am point source at 180^{o} scattering angle. Yılmaz *et al.* (2017) have studied the albedo factor determination of pure samples that the atomic number varied $26 \leq Z \leq 79$. They have carried out their work by using 5Ci strength ^{241}Am annular radioactive source at 168^{o} scattering angle. Sabharwal *et al.*(2009) have investigated the albedo and multiple backscattering features of some elements and alloys according to the target thickness and atomic number. The experimentally calculated values of the albedo and multiple backscattering were compared with the Monte-Carlo simulation method. The related experiment was carried out by using a small isotropic^{65}Znradioactive source that emitting 1.12 MeV gamma photons. Akkuş and Yılmaz (2019) have measured the mean atomic number effects on the albedo factor parameters of some selected samples that the mean atomic number varied at $9.743 \leq \bar{Z} \leq 83.00$. In this work, the ^{137}Cs radioactive source that emitted 662 keV gamma-photons was used at 180^{o} scattering angle. Kiran et al. (2016) have studied the albedo factor parameters of carbon, aluminum, iron and copper samples. In this work, 123, 320, 511, 662 ,and 1115 keV gamma photons that emitted from ^{57}Co, ^{133}Ba, ^{22}Na, ^{137}Cs ,and ^{65}Zn radioactive sources respectively, was used. The emitted photons were scattered from target samples at 180^{o} scattering angle. Yılmaz et al. (2020) have measured the albedo factor parameters of V_2O_5 thin films that were doped with selenium and boron compounds. The experimental setup was coupled with the 5 Ci ^{241}Am annular radioactive source. In addition, the radioactive source was emitted 59.54 keV gamma photons, and the emitted photons scattered from the target at a 168^{o} scattering angle.

In this study, the albedo factor parameters of some selected Cu compounds have been measured by using 5 Ci strength ^{241}Amradioactive source that emitted 59.54 keV gamma rays. The scattering angle is set up to 168^{o}.

2. Substance and Method

2.1. Experiential Details

HPGe semiconductor detector and radiation source were used in this experimental study. The experimental setup showing the experiment geometry and the system used is shown in Figure 1. Also, the sample chamber was used in the experimental setup and is shown in Figure 2.

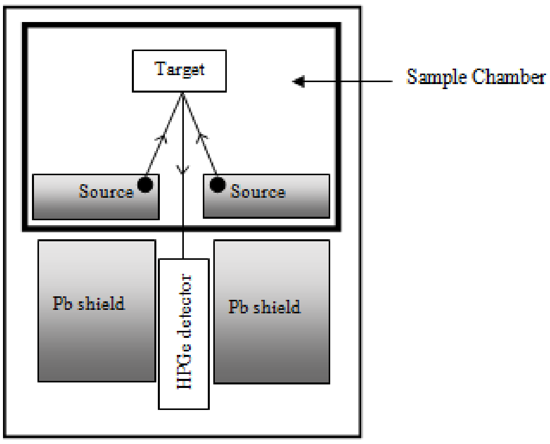

Figure 1. Experimental setup (radius of collimator is 0.53 cm). This figure is only a schematic diagram of experimental setup.

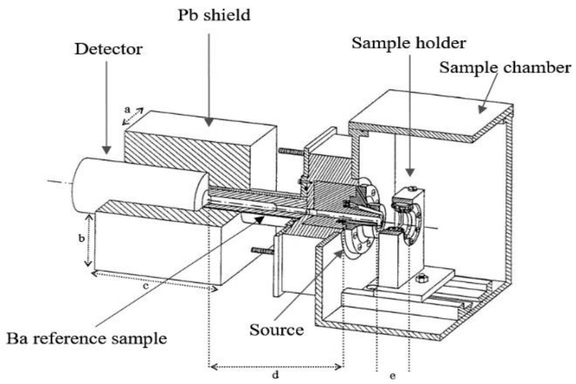

Fig. 2. Sample chamber (a=6.5 cm, b=6.3 cm, c=13.5 cm, d=11 cm, e=5 cm).

The main objective of using the sample chamber in this setup has divided into two. First of all, the usage of the sample chamber was provided to eliminate the hazardous effects of the radiation sources. The sample chamber has a conical shape and coated with a lead layer. The second objective of the usage of the sample chamber was related to this special structure. Therefore, the lead-coated and also, conically collimated sample chamber has provided as monochromatic gamma beam as possible. The collimated monochromatic gamma beams were directed to the sample chamber and scattered photons counted by using an HPGe semiconductor detector. The sample chamber used to collimate gamma beam and protect the researcher, completely covers the experimental setup. The collimated gamma beam was directed to the target at a 168^{0} scattering angle. This scattering angle provides us to avoiding from unexpected, scattered gamma beams.

High Purity Germanium (HPGe) detectors are systems that provide us to obtain sufficient, reliable, and accurate information from passive gamma rays emitting from radionuclides. HPGe detectors provide 20-30 times greater improvement in resolution than Sodium Iodide (NaI) detectors. Also, unlike HPGe detectors, NaI detectors have been shown to perform poorly in mixed isotope, shielded, off-count, and high baseline count situations. The radioactivity studying characteristics of the HPGe detector has been carried out by Demir et al. (2013).

2.2. Measurements of Albedo Factor.

The experimental setup was coupled with a computer-based multichannel analyzer system that namely Genie-2000. The Genie-2000 program is monitoring the characteristic photo peaks and providing the determination of photo peak areas. The determined photopeak areas have been processed by using the Origin 7.5 program. The photopeak areas have been consisting of the backscattered and incident components and represented by $N_{bs}$and N_i, respectively [7]. Therefore, these photopeak components were used in the calculation of the albedo number and have been given by the following equation,

$$A_N = \left[\frac{N_{bs} / \varepsilon(E_{bs})}{(N_i / \varepsilon(E_i))(1/\mathrm{d}\Omega)(1/2)} \right] \quad (1)$$

Also, the above-mentioned equation contains $\varepsilon(E_{bs})$ and $\varepsilon(E_i)$ terms. These related terms have been expressed the backscattered and the incident photo-peak efficiencies of HPGe detector, respectively. Another important term is the solid angle ($d\Omega$), and it is subtended by the detector by the collimator opening at the center of the target. A factor of *1/2* is included in the denominator because half of the gamma photons emitted by the radioactive source are incident on the target.

The calculation of the albedo number has been used in the derivation of the albedo energy parameter and related formula given by the following equation,

$$A_E = \left[\frac{E_{bs}}{E_i} \right] A_N \quad (2)$$

where E_{bs} and E_i are the backscattered and incident photon energies, respectively. Besides the last parameter of the albedo factor have been called albedo dose and the albedo dose is proportional to energy albedo that given by the following equation,

$$A_D = \left[\frac{\sigma_a(E_{bs})}{\sigma_a(E_s)} \right] A_E \quad (3)$$

The aforementioned equation (3) has contained $\sigma_a(E_{bs})$ and $\sigma_a(E_s)$ terms and these terms expressed by the energy absorption coefficient of air for backscattered and incident gamma photons, respectively. $\sigma_a(E_{bs})$ and $\sigma_a(E_s)$ absorption coefficients have been taken from XCOM photon cross-section database [8]. The air is composed of different elements in different percentages and these percentages taken from Table 1.

Constituent	Chemical symbol	Mole percent
Nitrogen	N_2	78.084
Oxygen	O_2	20.947
Argon	Ar	0.934
Carbon dioxide	CO_2	0.0350
Neon	Ne	0.001818
Helium	He	0.000524
Methane	CH_4	0.00017
Krypton	Kr	0.000114
Hydrogen	H_2	0.000053
Nitrous oxide	N_2O	0.000031
Xenon	Xe	0.0000087
Ozone	O_3	0.00000001

3. Result and Discussion.

Some selected copper (Cu) compounds have been used in the derivation experiments of the albedo factor parameters. The copper purified in refining furnaces is poured in various ways in order to give a different form according to the process to be subjected in the future. The most important form of casting is the wire bar. In addition, plate, angular, or cylindrical shaped casting types are among the most common ones. Copper large amount of ingot bars for alloys and for use in the chemical industry, it is cast in the form of copper granules. Copper obtained by electrolysis methods from copper sulfate and other liquid copper surpluses is especially used in the production of copper pipes and thin copper plates. In addition, copper powders in the shape and size suitable for the intended use are obtained by the electrolysis separation method. Because of its behavior against external factors, copper is the metal closest to the primary metals. It has a high resistance to acid and atmospheric conditions. Due to its feature, copper finds wide use as a semi-noble metal. In addition, copper has high tensile and fracture strength and can be easily cold formed with hammers and rolls. When hammered, very thin copper leaves can be obtained. 0.3mm with ease in industry copper wire can be made. It is known that in the past, copper was used in various places by taking advantage of its softness, strength, and workability. The areas of use in our time are mostly based on the later learned properties of copper. The most important of these features is that copper conducts heat and electricity very well. Copper is the best conductor of heat and electricity after silver and gold. For this reason, copper is the most dominant metal in electrical and electro technique and has also supported many new developments in these fields.

X-ray room shielding is one of the most mandatory procedures for X-ray rooms. It is forbidden to work without armoring procedures according to the regulations of the Ministry of Health. It is very, very important for human health. It is very important both for human health and for the stable operation of other devices. In order to prevent the radiation emitted by X-ray lights and to minimize the damages, it will cause, the rooms where X-rays are taken should be specially covered. In medical settings, especially in the chemotherapy of cancer patients undergoing chemotherapy treatment, X-rays should be shielded without damaging the room design and be well protected. Armoring is done with materials such as copper and lead to reduce the radiation intensity. The high level of radiation is reached to the maximum ideal level by shielding. How the ideal armor thickness should be determined by making some calculations. The calculation is based on the radiation dose value that may occur in overwork and the MMED value. It is used for heavy concrete armoring with lead, concrete, copper, barite aggregate. The materials to be used in armor vary according to the type of machine. Sometimes, in cases where radiation is low, armoring can be done with a light aluminum. However, the substance with the highest atomic number among the X-ray chambers shielding materials is lead.

In this study, the albedo factor analysis was carried out for some compounds of copper, which is one of the materials used in radiation shielding. As it is known, the albedo factor is only one of the radiation shielding parameters and it is divided into 3 groups as albedo number, albedo energy, and albedo dose. These radiation shielding parameters were measured by using the aforementioned experimental setup and derived via related formulas. The calculated values of the mentioned parameters were given by Figure 3-5. As shown in the figures, the albedo parameter values are decreasing with the increasing value of the atomic number of target samples. Increasing the photoelectric cross-section with increasing atomic number and decreasing Compton cross-section are the main reasons for this situation.

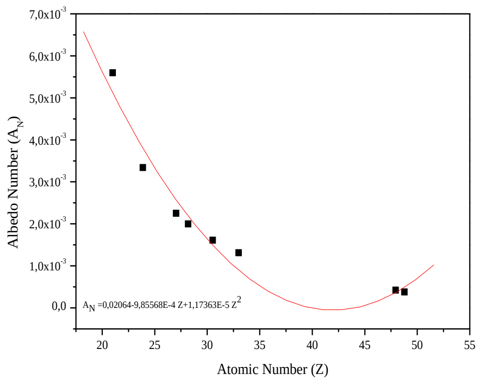

Figure-3. The albedo number distribution of target samples as a function of the atomic number.

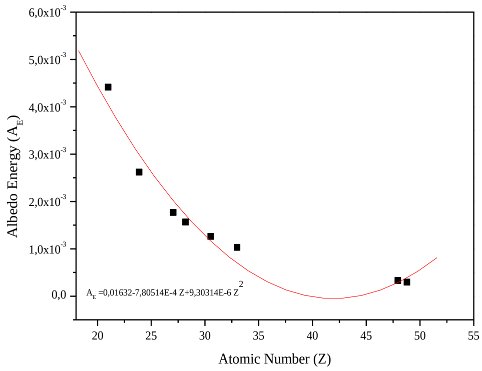

Figure-4. The albedo energy distribution of target samples as a function of the atomic number.

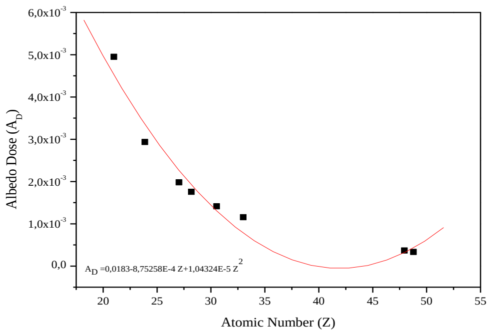

Figure-5. The albedo dose distribution of target samples as a function of the atomic number.

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