Effective atomic number of granite by gamma backscattering method

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Introduction

Composite materials which are mixtures of two or more elements are characterized by the term 'effective atomic number' (Z_{eff}). Study of Z_{eff} provides conclusive information about the mixture when gamma photons interact with materials [1]. Paramesh et al [2] showed that multiple backscattered photons increases for an increase in target thickness and then becomes almost a constant for a thickness called as saturation thickness. Their work showed that materials having higher atomic numbers have lower saturation thicknesses. Singh et al [3] used this technique to obtaine the effective atomic number of certain binary alloys.

The present paper describes the experimental method to find the effective atomic number of granite which is widely used for construction purpose. Using the elemental composition of granite, the theoretical effective atomic number is obtained and compared with the experimentally obtained value.

Method of measurements

The experimental set-up to measure the backscattered photons is shown in Fig. 1. Gamma photons of 662 keV are obtained using ^{137}Cs of strength 5.8 mCi from a well collimated system. The gamma spectrometer kept at a backscattering angle of 120° with respect to the source, consists of 76 mm × 76 mm NaI (Tl) scintillation detector. To avoid the contribution due to background radiations, the detector is shielded by cylindrical lead blocks. The entire experimental set-up was placed in the center of the room to minimize scattering from the walls.

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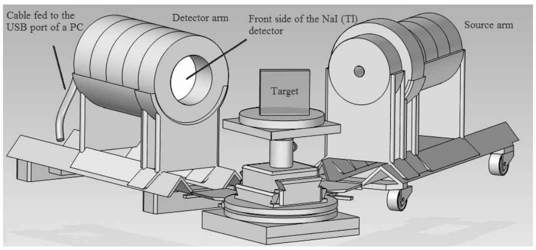

FIG. 1: Experimental setup.

Experimental data are accumulated on a PC based fully integrated *dMCA* gamma spectrometer. A software program using *winTMCA32* software package was written for the present experimental set-up to gamma backscattered events. The pulse height distribution obtained during experimental study contains both single and multiple scattered photons. Single scattered spectrum is reconstructed analytically using experimentally determined parameters such as full width at half maximum and efficiency of gamma detector [4].

Results and conclusions

Measurements of scattered photons are carried out as a function of sample thickness for rectangular targets of 100 mm × 100 mm using ^{137}Cs source. The dead time corrected acquisition time of 1000 seconds was used to acquire the data. Subtraction of single scattered photons from the response corrected noise-subtracted spectrum in a particular energy range results in multiple scattered photons only. This procedure is repeated for different thicknesses of carbon, aluminium, granite, iron and copper. A graph of multiple scattered photons versus target thickness is shown in Fig. 3. From the graph the saturation thickness of carbon, aluminium, granite, iron and copper are found to be 150 mm, 88 mm, 82.24 mm, 34.51 mm and 26.1 mm respectively.

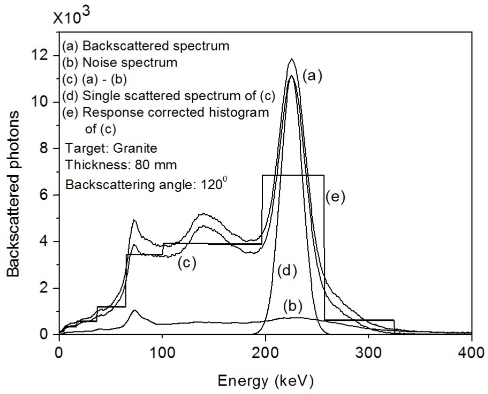

FIG. 2: Response corrected spectrum.

A graph of saturation thickness versus atomic number is plotted for carbon, aluminum, iron and copper and is shown in Fig. 4. From the best fitted graph for 4 points, using interpolation method, effective atomic number of granite having a saturation thickness of 82.24 mm is found to be 13.895.

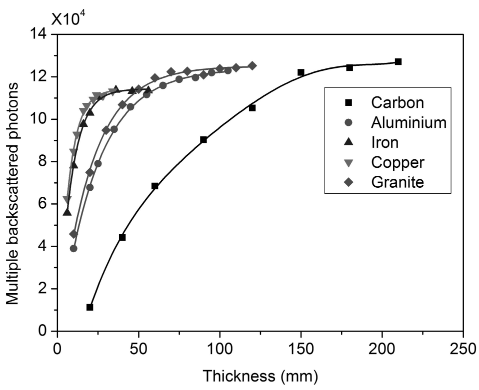

FIG. 3: Multiple scattered counts v/s thickness.

Elemental analysis of granite samples were carried out using X-ray fluorescence (XRF) facility at CESS (Centre for Earth Science Studies, Akkulam, Thiruvananthapuram, India) using Bruker model S4 Pioneer sequential wavelength dispersive X-ray spectrometer

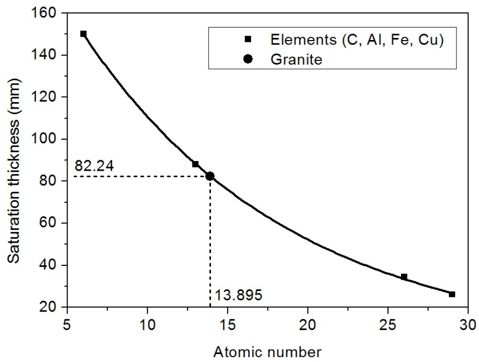

FIG. 4: Saturation thickness v/s Z.

and its elemental compositions (in %age) are found to be as follows: Al: 8.0392, Ca: 2.76, Fe: 2.71, K: 2.31, Mg: 1.11, Mn: 0.045, Na: 3.19, O: 48.1453, P: 0.18, S: 0.024, Si: 31.08, Ti: 0.2374.

Theoretically, the effective atomic number can be found by simple power law of the form $Z_{eff} = \sqrt[m]{\Sigma f_i Z_i^m}$ whereby the relative electron fraction of the i^{th} element Z_i is given by f_i, such that Σf_i=1. Using the elemental composition, by substituting the fractional weights and atomic numbers in the above equation, the theoretical effective atomic number of granite is found to be 13.0467.

Multiple gamma backscattered technique is a good non-destructive method to find the effective atomic number of composite material. The experimental and theoretical values of effective atomic number of granite are in good agreement to each other.

References

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