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NAA OF AN EGYPTIAN CERAMIC ELECTRIC INSULATOR SAMPLE

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ABSTRACT

In this work a sample of a ceramic electric insulator material used in Egypt in the production of transformers and indoor electric equipment has been elementally analyzed by Neutron Activation Analysis (NAA) technique. The Pneumatic Rabbit Transfer System (PRTS) of the 10 MW Budapest Research Reactor (BRR) was used, for short time irradiation of 120 s. Long time irradiation was performed at the reactor core periphery for 24 hours. The thermal neutron fluxes at full reactor power in both cases were 6 x 1013 n/cm2.s and 3 x 1013 n/cm2.s, respectively. The gamma-ray spectra obtained have been measured for several times by means of the Hyper Pure Germanium Detection System (HPGe). The ko computer programs were used for data analysis. A total of 42 elements have been identified as: *Na, Al, Cl, K, Sc, Ti, V, Mn, Fe, Co, Zn, Ga, As, Br, Rb, Sr, Zr, Mo, Ag, Sb, Te, Cs, Ba, La, Ce, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Tm, Yb, Lu, Hf, Ta, W, Ir, Au, Th* and *U.*

Key Words: Ceramics – Insulators – Neutron Activation

INTRODUCTION

Ceramics, (Greek *keramos,* "potter's clay") originally the art of making pottery, now a general term for the science of manufacturing articles prepared from pliable, earthy materials that are made rigid by high-temperature treatment. Ceramic materials are nonmetallic, inorganic compounds, primarily oxides, but also carbides, nitrides, borides, and silicides. Ceramics have characteristics that enable them to be used in a wide variety of applications including: high heat capacity and low heat conductance, corrosion resistance, electrical insulation, semiconductance, or superconductance, nonmagnetic and magnetic, hard and strong but brittle. The diversity in their properties stems from their bonding and crystal structures. Two types of bonding mechanisms occur in ceramic materials, ionic and covalent. Often these mechanisms co-exist in the same ceramic material. Each type of bond leads to different characteristics. Ionic bonds most often occur between metallic and nonmetallic elements that have large differences in their electronegativities. Ionically-bonded structures tend to have rather high melting points, since the bonds are strong and non-directional. The other major bonding mechanism in ceramic structures is the covalent bond. Unlike ionic bonds where electrons are transferred, atoms bonded covalently share electrons. Usually the elements involved are nonmetallic and have small electronegativity differences. Many ceramic materials contain both ionic and covalent bonding. The overall properties of these materials depend on the dominant bonding mechanism. Compounds that are either mostly ionic or mostly covalent have higher melting points than compounds in which neither kind of bonding predominates. Ceramic materials can be divided into two classes: crystalline and amorphous (noncrystalline). In crystalline materials, a lattice point is occupied either by atoms or ions depending on the bonding mechanism. These atoms (or ions) are arranged in a regularly repeating pattern in three dimensions (i.e., they have long-range order). In

contrast, in amorphous materials, the atoms exhibit only short-range order. Some ceramic materials, like silicon dioxide (SiO2), can exist in either form.

Ceramics vary in electrical properties from excellent insulators to superconductors. Thus, they are used in a wide range of applications. Some are capacitors, others are semiconductors in electronic devices. In 1986, a new class of ceramics was discovered, the high Tc superconductors. These materials conduct electricity with essentially zero resistance. Finally, ceramics known as piezoelectrics can generate an electrical response Piezoelectric materials can convert mechanical pressure into an electrical signal and are especially useful for sensors. Ceramics are probably best known as electrical insulators.

The sample under investigation is a ceramic electric insulator material commonly used in the production of transformers and indoor electric equipment. It is provided by the Egyptian company EGMAC [1] as one of the Ciba – Geigy chemical products.

De corte et al. had established the ko,Au factors and the related nuclear data used in the present work. The use of high[2,3] resolution HPGe detection system in NAA technique with application of the ko method is considered as one of the most precise tools for such purposes. The used pneumatic transfer rabbit system was described elsewhere[3].

EXPERIMENTAL

Irradiation:

For short- (120 s) and long- (24 hours) time irradiation, 21.4 mg and 0.015 mg of the sample provided by the EGMAC Company were used. The samples were ground in a powder form and compressed into pellet shape then sealed in polyethylene capsules. Each sample was associated with Zr foil and the convenient alloys of (Al-0.1% Au) and (Al-0.1% Lu) wires for determining the irradiation parameters f and α at the irradiation position. f is the thermal to epithermal neutron flux ratio and α is the deviation factor concerning the departure of the epithermal neutron spectrum from ideality (1/E law). In short irradiation, f=27.7 and α=0.0625. The thermal neutron flux at the core of the 10 MW BRR was about 6x 1013 n/cm2.s for short time irradiation while it was about 3 x 1013 n/cm2.s for the long time irradiation.

Measurements:

The (HPGe) detection system is used for measuring the gamma- rays emitted by the activated samples as well as the standard materials used for flux monitoring. The gamma-ray energy E (in keV) dependence of the detector resolution (FWHM) follows the empirical relation:

$$FWHM = 0.793 + 8.0\ 10^{-4}\ E\gamma + 6.2\ \ 10^{-8}\ E2\gamma$$

In case of the short irradiation time, three γ-ray spectrum (for Eg from 52 to 3356 keV) measurements for periods of 600, 1200 and 1800 seconds were carried out after cooling times of 240, 8940 and 81240 seconds, respectively. Figs. (1a), (1b) and (1c) show the gamma–ray spectra of the three runs. A total of 42 elements were identified in both cases of short- and long-time irradiation. Elemental identification was performed by using criteria based on the half -life time as well as the intensity of the well resolved gamma-ray lines each element. The concentration of each element was estimated by applying the KAY/ZERO/SOICOI program package [2,3] on the well resolved gamma-ray lines of each element.

RESULTS and DISCUSSION

Table (1) gives the concentration values (C) and their errors (C) in mg/kg for the identified 42 elements in the Egyptian ceramic electric insulator. It can be noticed that Al, Cl, and Fe can be considered as major elements, while Na, K, Ti, V, Mn, Zn, Rb, Sr, Zr, Mo, Ba La, Ce, Nd, Hf and Th

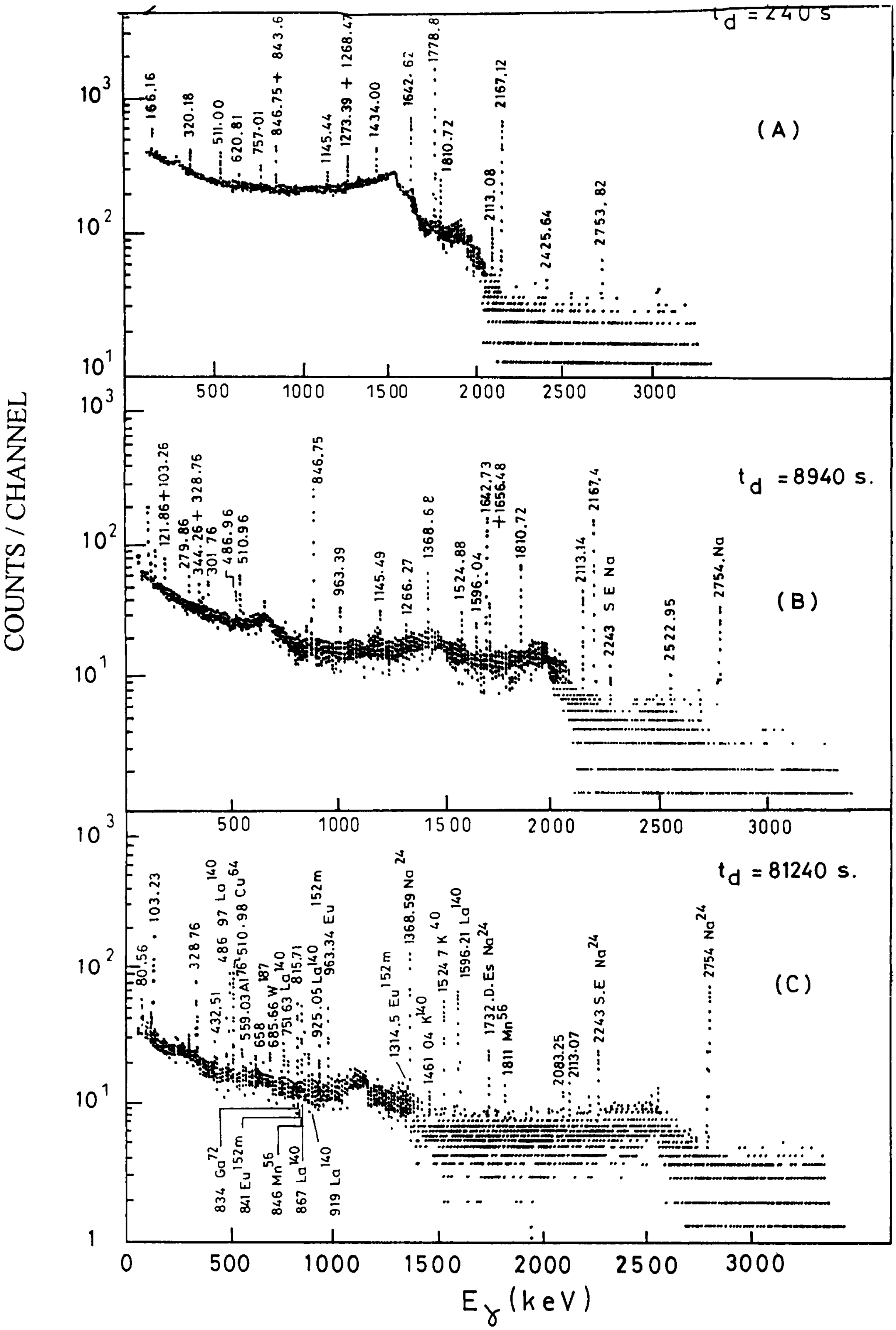

Fig. (1). Gamma - Ray Spectrum of the Electric Insulator Sample (Irradiation time = 120 s.) with different decay times, (A) t_d =240s, (B) t_d =8940 s, and (C) t_d =81240s can be considered as minor elements. The remaining 23 elements are present in a trace level (< 1 mg/kg). The concentration values of the major, minor and trace elements presented in this sample have a great importance in assigning the physical properties (Elasticity, homogeneity, insulation properties, stability and mechanical properties) and in turn the quality of the material [4-11].

The high aluminum content in the sample may indicate that it is manufactured from alumina clay. The existence of titanium may indicate that it is an aluminum titanate (Al2Ti05) based material. Aluminum titanate is also a material suitable for an application at higher temperatures, resistant to thermal shocks, and an excellent thermal insulator. Ceramics are probably best known as electrical insulators. The existence of Ba may indicate the presence of BaTiO3. Some ceramic insulators (such as BaTiO3) can be polarized and used as capacitors. Other ceramics conduct electrons when a threshold energy is reached, and are thus called semiconductors.

Table 1.The Concentration Values of the Elements Identified in the Egyptian Ceramic Electric Insulator Sample.

Element	Concentration (C) mg/kg	Error (±Δ C)	Element	Concentration (C) mg/kg	Error (±Δ C)
Na	29.3	0.5	Cs	0.180	0.004
Al	1980	6	Ba	44.0	1.6
Cl	3320	20	La	5.76	0.04
K	316	22	Ce	12.80	0.04
Sc	0.160	0.002	Nd	5.30	0.18
Ti	203	10	Sm	0.7416	0.0002
V	1.40	0.09	Eu	0.083	0.004
Mn	5.97	0.05	Gd	0.650	0.044
Fe	1320	11	Tb	0.087	0.001
Co	0.120	0.002	Dy	0.46	.01
Zn	2.200	0.064	Ho	0.25	0.01
Ga	0.350	0.053	Tm	0.040	0.006
As	0.200	0.018	Yb	0.280	0.003
Br	0.16	0.02	Lu	0.043	0.003
Rb	2.10	0.15	Hf	1.36	0.02
Sr	10.0	2.6	Ta	0.072	0.002
Zr	61.0	1.7	W	0.2955	0.0001
Mo	1.40	0.06	Ir	0.0030	0.0002
Ag	0.130	0.008	Au	0.0008	0.000
Sb	0.031	0.002	Th	3.46	0.01
Te	0.73	0.07	U	0.7541	0.0003

CONCLUSION

On conclusion, attention may be drawn to the feasibility of the NAA with HPGe detection system in industrial applications. The k0 standardization method improves the precision of the results to a great extent.

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