X Congreso Regional Latinoamericano IRPA de Protección y Seguridad Radiológica
"Radioprotección: Nuevos Desafíos para un Mundo en Evolución"
Buenos Aires, 12 al 17 de abril, 2015
SOCIEDAD ARGENTINA DE RADIOPROTECCIÓN

ONYX SAMPLES CHARACTERIZATION BY OSL TECHNIQUE FOR HIGH-DOSE DOSIMETRY

Teixeira, M.I.[1,2], Caldas, L.V.A.[1]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN/SP),
[2] Associação Educacional Nove de Julho (UNINOVE/SP)

ABSTRACT

Onyx samples were studied in this work to verify their dosimetric properties. The Onyx stone is considered nobler than marble. At IPEN, the radiation metrology group has studied new materials for application in high-dose dosimetry. The Onyx samples were exposed using a Gamma-Cell 220 system (^{60}Co), for doses of 50 Gy up to 300 kGy. The lower detection doses, the reproducibility of the OSL response and calibration curves were determined. All three types of Onyx samples showed good behavior for high-dose dosimetry.

1. INTRODUCTION

High-doses of gamma radiation have been utilized in the pharmaceutical industry for sterilization of materials and also in agriculture (desinfestation, inhibition of sprouting) [1]. McKeever [2] reported results on silicates as a research source for solid state dosimetry. Teixeira e Caldas has already studied some materials such as glasses [3], sand [4, 5] and jasper [6] for high-dose dosimetry. Other ddifferent materials have already been studied in recent years at IPEN, for high-dose dosimetry using the thermoluminescence (TL), electronic paramagnetic resonance (EPR), optical absorption (OA) and optically stimulated luminescence (OSL) techniques [5,7,8].

Onyx was one of the most important stones for adornment and therapeutic use in antiquity. Several people used the onyx stone amulet as something strong and powerful. The name derives from the Greek onyx (nail), because it was thought to be the fingernails of Venus by falling to the earth [9]. The Onyx is a semiprecious stone found in Brazil, Uruguay and India. It is a type of chalcedony, a variety of quartz with a hardness of 7 (Mohr scale) and specific gravity between 2.65 and 2.66. It has high density and metallic luster after faceting [10]. Its basic material is silica with a chemical composition of silicon dioxide (SiO_2) with traces of zinc. The stones are presented with straight and parallel tracks and the colors commonly distributed in rings, and they are black and white, sometimes with alternating shades of gray with white and brown colors. The Onyx metallic appearance is due to the presence of small amounts of gold, platinum, copper or iron [11]. The black Onyx is the most appreciated type, and its commercial name is real-Onyx.

Onyx samples are found in nature in abundance in Brazil, in the Minas Gerais and Paraná States. The Onyx stone is considered nobler than marble.

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[1] E-mail del Autor. miteixeira@ipen.br

The possibility of application of Brazilian Onyx samples for high-dose dosimetry was already studied at IPEN, using the thermoluminescence technique [12], (Teixeira et al., 2011). The white, black and striped onyx samples are reported in this work using the technique of optically stimulated luminescence (OSL).

2. MATERIALS AND METHODS

The onyx stones were extracted from a Brazilian mine (white, black and striped), in the Minas Gerais State. The Onyx stones were washed and pulverized to wrapped grains of diameter between 0.074 and 0.177 mm. The Onyx powder was subjected to a thermal treatment of 300 ^{0}C for 1 h. At the Radiation Metrology Laboratory, pellets (50mg) with powdered Teflon and onyx of proportion of 2:1 were prepared in open atmosphere of nitrogen. The Onyx-Teflon pellets were prepared with 6 mm of diameter and 2 mm of thickness.

The pellets were thermally treated for reutilization at 300°/1h. The irradiations were performed using a Gamma-Cell 220 system of ^{60}Co (dose rate of 1.52 kGy/h) for doses of 50 Gy up to 300 kGy, at the Center for Radiation Technology, IPEN. The irradiations were made at ambient temperature; to guarantee the occurrence of electronic equilibrium during the irradiations, the samples were covered with 3 mm thickness of a PMMA plate (polymethyl methacrylate), and packed in aluminium foils. The irradiations were made at ambient temperature.

The OSL measurements were taken using a RISÖ TL/OSL Reader and Controller, model DA-20, and the data acquisition were realized using a personal computer. All OSL measurements were taken from ambient temperature up to 300 ºC, using a constant flow of N_2 of 2.5 L/min.

3. RESULTS

In order to verify the possibility of utilization of Onyx pellets in high-dose dosimetry, their properties were studied using the OSL technique. The OSL emission curves were obtained during 60s. Figure 1 shows the OSL response of the Onyx samples (white, black and striped), irradiated with a dose of 5 kGy (^{60}Co). The pellets of white Onyx presented the maximum OSL intensity in relation to the OSL response of the black and striped Onyx samples.

The reproducibility of the OSL response of Onyx samples were obtained in the interval from 0°C to 300°C. Five sets of Onyx-Teflon pellets were subjected ten times to the same procedure of thermal treatment at 300°C/1h (defined for reutilization), irradiation (10 kGy) and OSL evaluation.

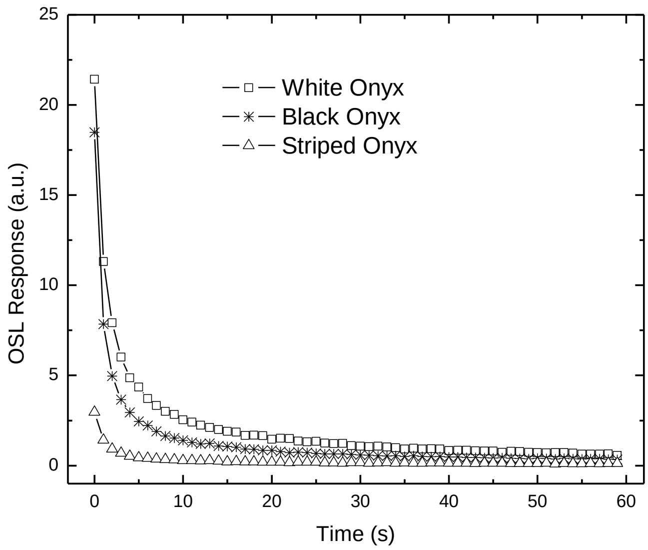

Figura 1. OSL response of Onyx-Teflon pellets irradiated with 5 kGy (^{60}Co)

The calibration factor of each sample was obtained by the quotient between the value of the absorbed dose and the average value of their responses. In this experiment the reproducibility is given by the percentual coefficient of variation (CV%), that is the quotient between the standard deviation of the measurements and the average of measurements of each pellet. The maximum standard deviations of 2.6%, 3.0% and 2.8% were obtained using the OSL reader respectively.

The OSL dose-response curves of the Onyx pellets were obtained for ^{60}Co, after thermal treatment at 300°C/1h and irradiation in the range of 500 Gy to 300 kGy. The dose-response curves of Onyx samples are presented in Figure 2; these measurements showed a maximum relative standard of 3.2%.

All Onyx samples suggest a sublinear behaviour of their responses in the studied dose range. The white, black and striped Onyx samples present OSL response saturation at 100 kGy, 30 kGy and 100 kGy respectively.

Lower detection limits of the Onyx-Teflon samples were obtained taking three times the values of the standard deviation of eight measurements of three non-irradiated Onyx samples of each type (thermal treatments at 300°C/1h), expressed in units of absorbed dose. The lower detection limits obtained were: 30 mGy, 45 mGy and 75 mGy, for the white Onyx, black Onyx and striped Onyx samples, respectively.

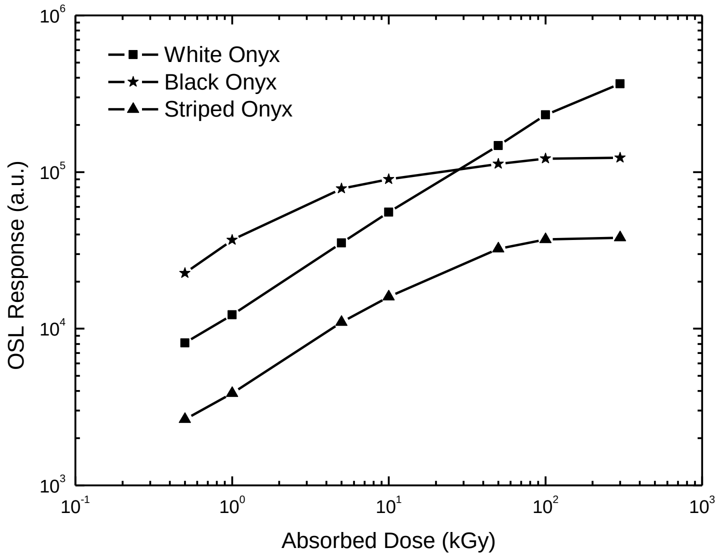

Figura 2. Dose-OSL response curves of Onyx-Teflon pellets for ^{60}Co radiation

4. CONCLUSIONS

The results on the main dosimetric propertis of Onyx samples show that they may be useful for high-dose dosimetry in industrial processes and in the sterilization of materials in hospitals. The basic advantage of Onyx samples is their very low cost and their usefulness for high-dose dosimetry using the OSL technique. An advantage of the OSL technique is that the measurements can be carried out several times. All three kinds of tested Onyx samples showed their usefulness as irradiation indicators (as changing their color depending on the absorbed dose) and as high-dose dosimeters.

ACKNOWLEDGEMENTS

The authors thank the Laboratory of Dosimetric Materials of IPEN/CNEN for the preparation of pellets, and the Brazilian agencies CNPq, CAPES and FAPESP, for the partial financial support.

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