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Opto-electric and physio-chemical changes in oxygen ion irradiated natural Vermiculite mineral

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HIGHLIGHTS

- Natural Vermiculite was irradiated with 80 MeV of oxygen ion for the first time.
- Cody model was employed to calculate structural disorder using optical spectra.
- Dielectric properties were significantly enhanced by the irradiation process.
- FTIR spectra show the disappearance of chemisorbed CO_2 band at higher fluences.
- Vermiculite was found as a suitable candidate for radiation dosimetry applications.

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ABSTRACT

The influence of 80 MeV O^{6+} ion on Vermiculite mineral in terms of its optical, dielectric, structural, chemical, and thermoluminescence (TL) properties have been reported in this paper for the first time. The structural disorder was computed from Urbach energy using Cody model, and was applied to reveal the variation of optical band gap with ion fluence. The ac conductivity (σ_{ac}) in both pristine and irradiated samples was found to obey Jonscher's power law. The mean crystallite size, micro strain and dislocation density were estimated from the analysis of X-Ray Diffraction pattern. The results of optical and dielectric parameters were found to be corroborated with structural changes of pristine and irradiated samples. FTIR spectroscopy of the samples reveals the broadening of bands and the decrease in overall intensity of the transmittance with the increase in ion fluence. Thermoluminescence studies were also performed to explore the dosimetric aspects of vermiculite. A prominent TL peak was observed around 148 °C to make Vermiculite a good dosimeter for eminent uses in radiation rich environs.

1. Introduction

In recent years, Swift heavy ion (SHI) irradiation furnishes several interesting and utilitarian aspects in understanding the damage and material modifications to encourage its use for the development of insulating systems and dosimeter in radiation rich environment (Kaur et al., 2017). Energetic charged particles lose their energy by excitation and ionization processes on passing through the solids (dielectrics) and cause the radiation damage in materials along the path of the particle (Fleischer et al., 1965; Singh and Singh, 1989). This radiation damage is also responsible for the changes in the structural, physical, optical and dielectric properties of the exposed material (Singh, 1999). Ion irradiation of phyllosilicate minerals can induce irreversible modifications of their macromolecular structure, in a controlled way, leading to remarkable changes in their structural, chemical, optical and electrical properties (Kaur et al., 2013a, 2013b, 2017). Among various phyllosilicate minerals, Vermiculite is the most unique clay mineral, having higher applicability in good insulation, fire resistance, agriculture, horticulture and industrial markets (Strand and Stewart, 1983; Hindman, 1992; Bergaya et al., 2006). Vermiculite has high-level exfoliation property because of water located between the layers (Mathieson and Walker, 1954). Nowadays, Vermiculite is in demand due to its high thermal resistance and good insulating properties for applications in advanced materials, insulation, building industry and ceramics (Klein and Dutrow, 2007) and for high gamma radiation shielding (Kaur et al., 2014).

Several authors (Sakharov et al., 2001; Campos et al., 2009; Marcos et al., 2009; Muiambo et al., 2010; Marcos and Rodriguez, 2011;

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