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The study of some properties of Aluminum Oxide AL_2O_3 Irradiated with Heavy Ions

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Abstract

The Optical, Mechanical and Thermoluminescence properties of Single Aluminum Oxide crystal AL_2O_3 irradiated with heavy ions with energy about 1 MeV ion/amu are considered. The results will show that the optical absorption of the irradiated sample exhibits two peaks; a well resolved one at around 200 nm and another unresolved one around 260 nm. They will also show that the relative hardness increases with increasing ion doses and reaches a nearly constant value. The results will show that the Thermoluminescence exhibits different peaks at different temperatures for different ion doses.

Keywords: Optical properties; Mechanical properties; Thermoluminescence; Heavy ion irradiation

Introduction

Sapphire is one of the most studied insulators by both pure and applied scientists and a large body of literature has developed concerning the intrinsic properties of the perfect crystal and the defect state **[1]**. It is well known that the ion implantation modifies the physical and chemical properties of materials. Therefore, material irradiation with ion beams has very interesting and practical applications such as implantation into semiconductors, metals and insulating materials. Furthermore, the use of energetic ion beams bringing about modifications in some important materials has become a wide field of basic research as well as a powerful technique for several studies and applications **[2,3]**. High-energy ions loose their energy in matter due to the elastic collisions and electronic excitations. More than half of the electronic energy loss is located within a small cylindrical region around the ion trajectory (ion track). The processes appearing in tracks of incident ions due to a high level of electronic energy loss are the most important ones.

At present, there has been enough experimental data to show that these processes determine to a considerable extent the main peculiarities of the sampled crystal microstructure that are formed under high- energy ion irradiation especially in dielectrics and semiconductors.

The use of high energy heavy ions has been increasingly of interest in the modification of materials through deep implantation. The interaction between these ions and solid atoms introduce radiation damage into insulators along the ion tracks due to electronic excitation processes **[4]**.

A few theoretical models are available to explain the structural defects induced by high-energy ion excitations, however the mechanisms of energy transfers from excited electrons to target atoms and defect creation have not been well understood.

One of the results of the electron subsystem excitation in ion tracks is the electromagnetic emission in ultraviolet, visible and infrared ranges of the optical spectrum, i.e. ion stimulated luminescence. Every band in the spectrum is associated with a certain type of ion-stimulated recombination or annealing part of the defects resulting from elastic collisions, impurity migration along the ion tracks and formation of high pressure local regions. There are various agents participating in this process and its previous stages: excitons, charge carriers, point defects, impurity atoms etc. **[5]**

The aim of the present work is to measure the change in the mechanical properties such as the relative hardness of Aluminum Oxide AL_2O_3 implanted by heavy ions at different doses, and the change in the optical properties such as the absorption at different wavelengths and the Thermoluminescence at different temperatures ranging from 100 C^o to 400 C^o.

Experimental

Single crystal Aluminum Oxide AL_2O_3 samples are irradiated using Kr ion beams with different doses.

The Optical absorption spectra experiment of the sample irradiated with Kr at 245 MeV, is performed by using an UV/VIS 8500 Double-Beam Spectro-Photometer at room temperature with different wavelengths. All spectra results are analyzed and fitted as a sum of Gaussian curves.

The hardness measurements were performed in the Solid State Laboratory using Shimadzu Micro Hardness Tester (HMV-2000) with an indenture of a diamond prism and edge of angle 136^0. We used TRIM program to approximate the concentration depth profiles of the implanted heavy ions Kr. The mean projected range R_p for the Kr ion is located at about 17.6 micrometers **[6].**

The TL measurements were performed using Harshow model 4000. The read-out heating rate was 8 C^o/s. The maximum read-out temperature was 400 C^o. The TL signal was normalized over the mass of the sample in order to follow the growth of the various TL glow peak as a function of dose in order to extract information regarding the influence of the heavy ion irradiation.

Results and Discussions

Figure 1 shows the measurements of the optical absorption of AL_2O_3 irradiated with Kr at 245 MeV for different doses.

The intensity of the absorption spectra has two peaks. One is well resolved at around 200 nm and the second one is weakly resolved at around 260 nm. At the beginning of irradiation, there are no defects. After the irradiation begins, a number of defects are induced. This leads to formation of F centers **[7]**; one oxygen vacancy trapped with one electron. The intensity of these bands is increasing with the increase of the irradiation **[8]**. The same process occurs with F+ centers, where the increase of the irradiation leads to the increase of the number of defects. After reaching the peak, the intensity decreases due mainly to the process of destruction of defect centers leading to amorphization of the material. The figure also shows that the intensity of the optical absorption intensity increases with the increase of the ion dose for the same wavelength.

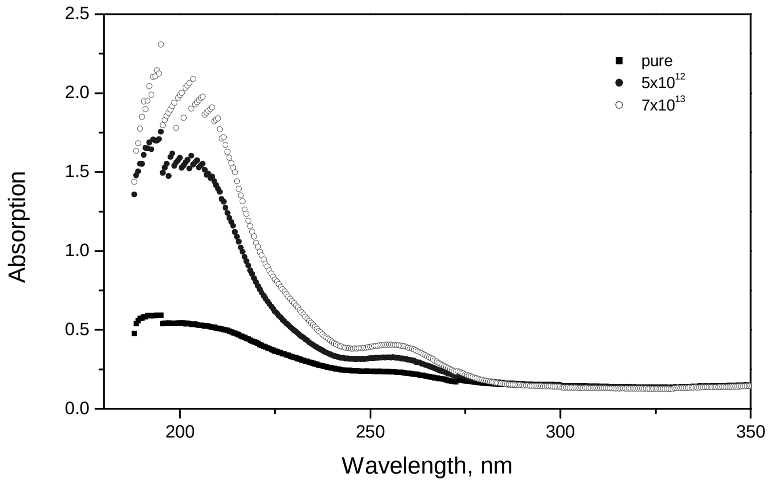

Figure 1: Absorption spectra for different doses of 245 MeV Kr ion irradiation.

Figure 2 shows the measurements of relative micro hardness of AL_2O_3 irradiated with Kr ion at 245 MeV for different doses. We observe that the relative hardness increases with the increase of ion dose and it reaches a saturation stage **[9-11]**. This increase is a result of the formation F and F+ centers due to overlapping of radiation defects and reaching a saturated state.

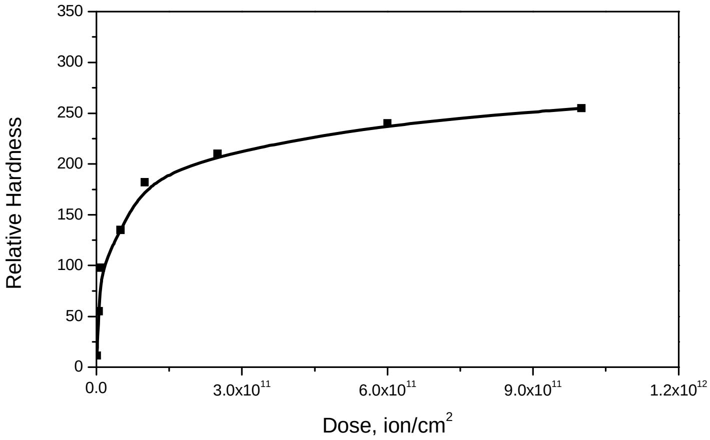

Figure 2: Relative hardness for different doses of 245 MeV Kr ion irradiation.

Figure 3 shows the measurements of the Thermoluminescence of AL_2O_3 irradiated with Kr ion at 245 MeV for different doses. The results exhibit a main glow curve at different temperatures for different ion dose. With increase in ion dose, an increase of F and F+ centers and saturation of defects due to very high local dose around the ion path occur **[12,13-15]**. The TL intensity is at its peak and then starts decreasing. This may be due to the increase in concentrations of trapped electrons (F-centers) in lattice as a direct consequence of the primary defect centers generated in the irradiated AL_2O_3 **[8,13-15]**.

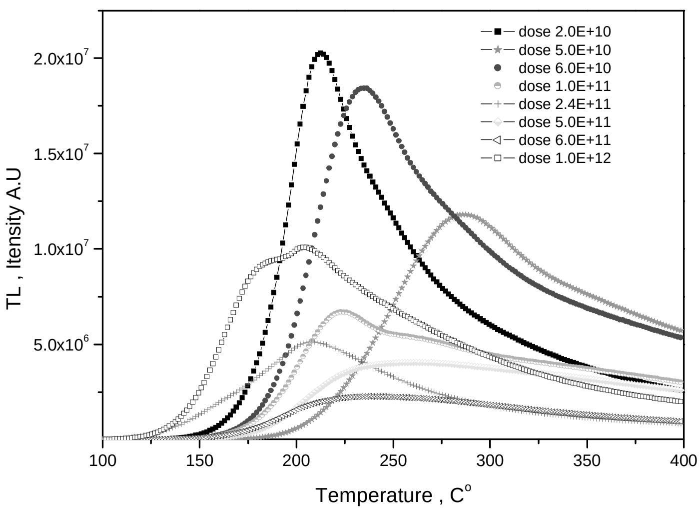

Figure 3: Thermoluminescence spectra for different doses of 245 Mev Kr ion irradiation.

A broadening in TL intensity is observed due to increasing of the ionizing radiation and a high concentration of luminescence centers (F-centers)**[10]**.

From the data exhibited in the figure 3, we can summarize the peak information of the TL intensity and the corresponding temperature for various Kr ion dose in the table below:

Ion Dose ($x10^{10}$ions/Cm^2)	**2.0**	**5.0**	**6.0**	**10.0**	**20.0**	**50.0**	**60.0**	**100.0**
Peak Temperature(C°)	**213**	**285**	**235**	**223**	**207**	**235**	**232**	**204**
Intensity ($x10^6$ A.U)	**20.0**	**12.0**	**18.0**	**6.7**	**5.1**	**3.8**	**2.3**	**1.0**

From the above table, we can display the average TL intensity and the peak temperature as a function of the ion dose in figures 4 and 5.

Figure 4 shows that the average TL intensity of AL_2O_3 under Kr ion with 245 MeV decreases sharply with increasing ion dose between **2.10^{10}** ions/cm^2 and **2.10^{11}** ions/cm^2 and then remains nearly constant.

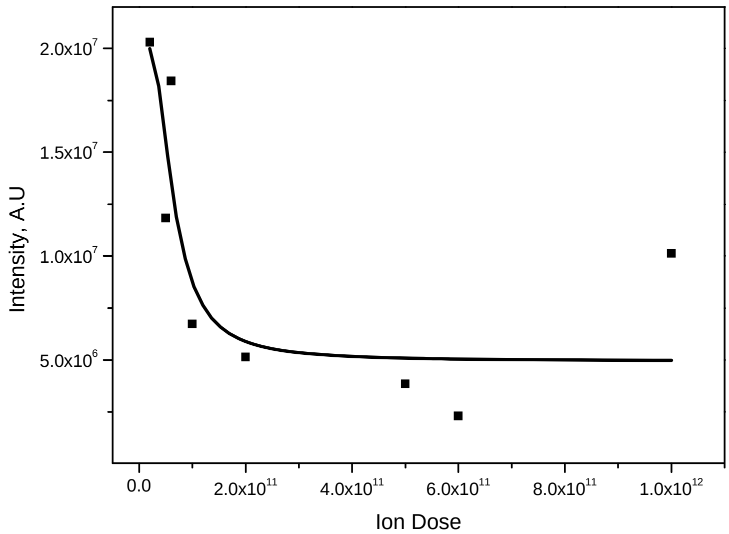

Figure 4: Average Thermoluminescence intensity as a function of Kr ion dose.

Figure 5 shows shifts in the peak temperature positions. The statistical average of the peak temperature corresponding to the TL intensity decreases relatively with increasing ion dose.

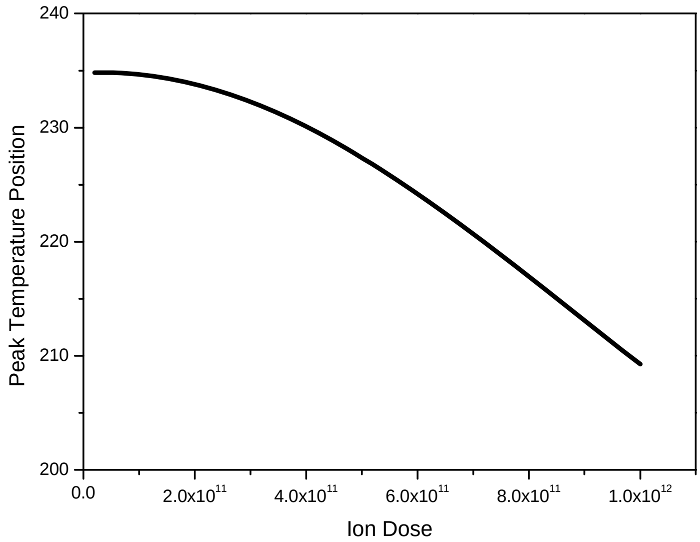

Figure 5: Average Peak Temperature as a function of Kr ion dose.

Conclusions

In conclusion, our experimental results of single crystal Aluminum Oxide AL_2O_3 irradiated with Kr ions show that its optical, mechanical and thermal properties are a direct consequence of the F and F^+ centers in the early creation stage and at the saturated stage and they all depend on the ion energy and ion dose. The absorption spectra shows two peaks: one at 200 nm and another at around 260 nm, the relative hardness increases with increase ion dose and reaches a saturation stage and the Thermoluminescence exhibits different peaks at different temperatures for different ion dose.

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