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ANNEALING CHARACTERISTICS OF NUCLEAR TRACKS IN GLASS DETECTORS USING OPTICAL ABSORPTION SPECTROSCOPY

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The etching and annealing behaviour of heavy ion nuclear tracks have been studied in glass detectors namely sodalime, phosphate and quartz using optical absorption spectroscopy. All these glass detectors were exposed at 90° and 45° for different ions, with collimated beams of varying energies. The absorption difference spectrum was employed to describe the annealing kinetics. A mathematical relation proposed in our laboratory was used to explain the annealing behaviour of radiation damage due to heavy ion beams in glass detectors. The activation energy was obtained from a new formulation and is found to be 0.16 eV in sodalime, 0.56 eV for phosphate and 0.69 eV for quartz glass detectors.

When glass is exposed to radiation, numerous changes in the physical properties can take place, e.g. optical absorption bands may be introduced, nuclear tracks can be formed, disruption of glass structure can take place, the density of glass can change, paramagnetic defect centres can be formed and the physical strength of a glass can be altered.

It is well known that the irradiation of a material by particles produces not only atomic displacements but also ionizing events. However, Frieble and Griscom[1] maintained that irradiation of glass produces defect centres and explained how these centres are formed on atomic level. They described the two principal interactions of radiations with glass as the ionization of electrons and direct displacement of atoms by elastic scattering. When the glass is subjected to ionizing radiations (α or γ ray photons, ultraviolet light or charged particles), electrons are ionized from the valence band if the energy of the radiation is greater than the band gap and the excess energy is converted to kinetic energy. Then the electrons move through the glass matrix and will either be trapped by pre-existing flaws to form defect centres in the glass structure, recombine with the positively charged holes, or in the case of high energy electrons produce a secondary electron cascade by knock-on collisions with the bound electrons.

The electronic structure of many of the radiation induced defect centres in both glass and crystalline materials is amenable to study by experimental tools such as optical absorption spectroscopy[2]. In fact, the visible absorption often induced by radiation in these materials has led to the term *colour centres* to describe the defect centres.

The irradiation of glass also results in induced optical absorption which can cause the glass to colour. The absorption arises because the splitting between the ground and excited states of the radiation induced defect centres is such that optical phonons iduce transitions between the states.

The important point about radiation effects in glass is that the radiation induced defects studied by various techniques arise because of hole or electron trapping so, there is a probability of thermal untrapping that may be described as:

$$P = S \exp(-E/kT) \qquad (1)$$

where S is the escape frequency and E is the height of the barrier[3]. This untrapping can result either in recombination or in retrapping at the same or different defect sites.

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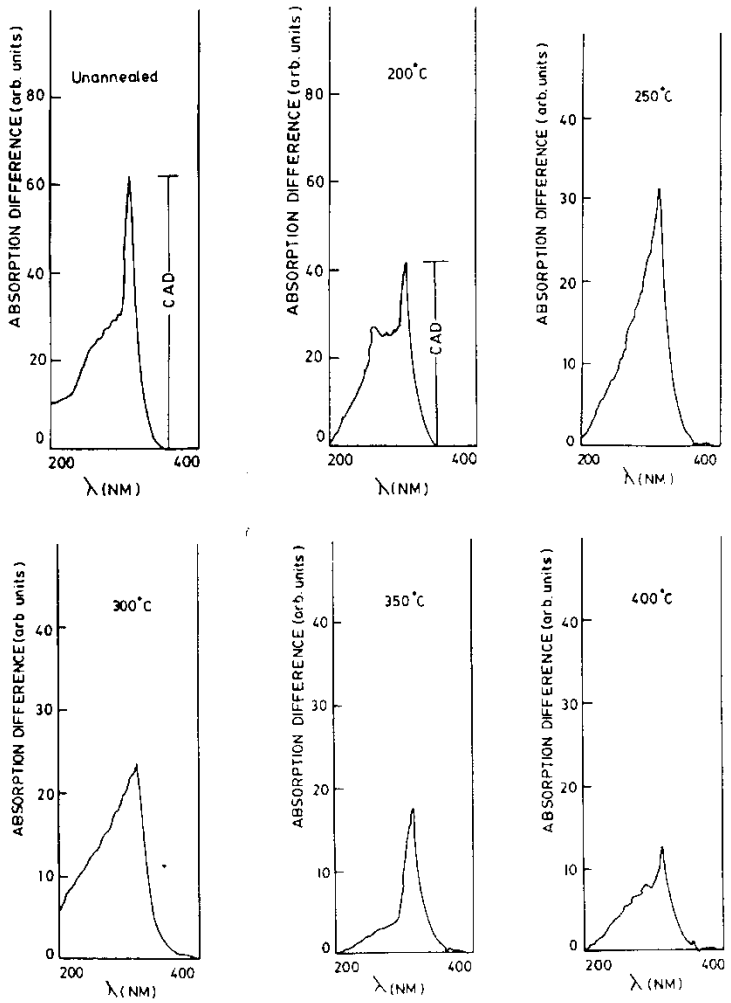

Fig. 1. The Characteristic Absorption Difference (CAD) for unannealed and annealed samples of sodalime glass irradiated with ^{139}La (14.6 MeV/n).

Table 2 - The comparison of activation energies in different glasses irradiated with varying ion beams.

Ion Beams	Activation Energy (eV)		
	Sodalime	Phosphate	Quartz
^{208}Pb (17 MeV/u)	0.16	0.56	0.69
^{208}Pb (13.6 MeV/u)	0.155	0.56	0.69
^{139}La (14.6 MeV/u)	0.16	0.56	0.69

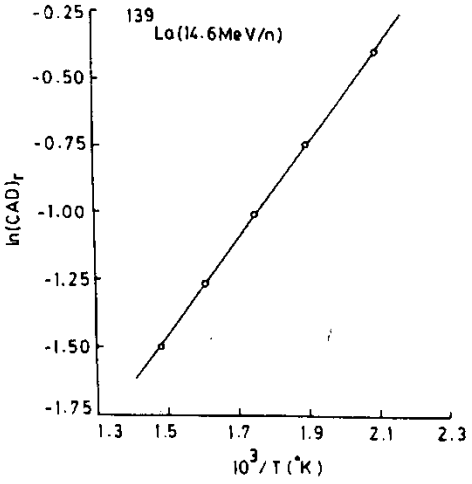

Fig. 2. The plot of ln (CAD)$_f$ against inverse temperature using ^{139}La (14.6 MeV / n) ion beam in sodalime glass detector

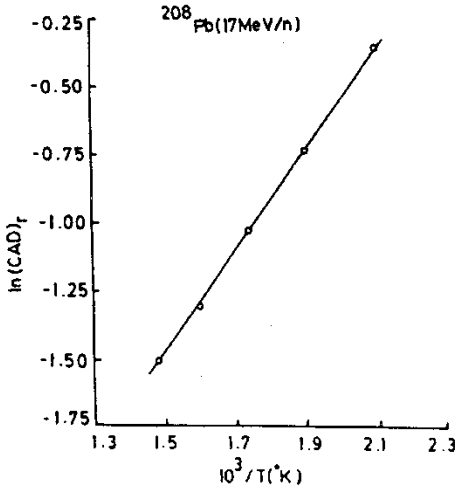

Fig. 3. The plot of ln (CAD)$_f$ against inverse temperature using ^{208}Pb (17 MeV / n) ion beam in sodalime glass detector.

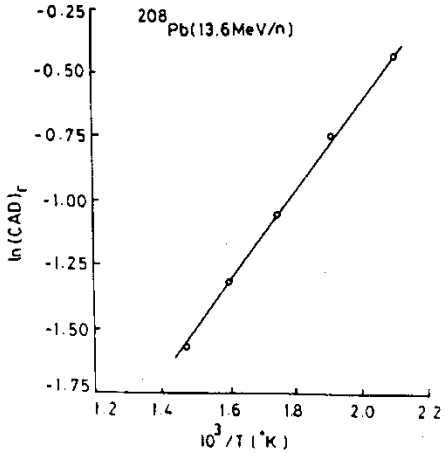

Fig. 4. The plot of ln (CAD)$_f$ against inverse temperature using ^{208} Pb(13.6 MeV / n) ion beam in sodalime glass detector.

Conclusions

Therefore, we may conclude that:

1. Identical values of activation energies obtained for different radiation sources implies that similar elementary process are operative for the annealing of radiation damage caused by the different ionizing radiations.

2. The new approach of calculating the activation energy using absorption apectroscopy further strengthens the concept that a single activated process is involved during annealing of a radiation damaged glass.

3. The present results are in agreement with our previous findings[16-17].

4. While constructing empirical formulations, the simple formulations with less fitted parameters are generally preferable.

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