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Some thermoluminescence properties of synthetic quartz and its potential as high level gamma radiation thermoluminescence dosimeter material

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Abstract : The present paper reports the thermoluminescence (TL) glow curves observed in powder of 230–350 mesh grain size of synthetic (laboratory made) quartz crystals with and without gamma irradiation. It is found that the specimen does not exhibit natural thermoluminescence (NTL). The excitation of the material at room temperature with gamma radiation induces TL peaks at 110°C [peak-I], 210°C [peak-II] and 340°C [peak-III] temperatures. Among them, peak-I is found sensitive to low gamma doses and found absent in higher doses In contrast to this, peak-II appears only at higher doses [70 Gy–6 kGy]. The examination of various dosimetric properties encourages the authors to suggest that peak-II present in synthetic quartz can be of use in the estimation of the higher-level-gamma doses used in radiation processing applications [100 Gy–6 kGy].

Keywords : Thermoluminescence, synthetic quartz.

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In modern days, radiation processing have become an important tool to solve large number of practical problems in the present scientific world. The basis of any radiation processing application is the initiation of chemical reaction through ionizing radiation such that it destroys micro-organisms of the radiated material. The radiation dose required in this process is in the range of 100 Gy to 6 kGy. The natural and synthetic quartz materials have been utilized by many investigators for dose estimation (particularly low-level-dosimetry up to 70 Gy) [1–4]. In the present paper, the synthetic quartz crystal in powder form have been examined for its thermoluminesence behaviours to find out its utility in high-level-gamma radiation dosimetry. The TL results obtained in different physical conditions are presented in the paper. The attempts have been made to find the use of the TL peaks in high-level-radiation dose estimation required in radiation processing. The discussion in this direction has been given in the paper. It is found that 210°C [peak-II] is sensitive to only higher radiation doses and it will be suitable for dose estimation.

In the present investigation the laboratory-grown synthetic quartz crystal was powdered to the uniform grain size for the record of TL. The TL glow curves in the present work have been recorded by means of NUCLEONIX model TL 1007 which is a compact, self-contained PC-based TL system. For each measurement, 5 mg of the synthetic quartz sample was taken. For excitation purpose, Co^{60}-gamma source having its uniform irradiation rates of 16.49 Gy per minute (1 Gy = 1 J/kg) at the irradiation position was utilized. The quartz crystals have been grown at Center for Glass and Ceramic Research Institute (CGCRI), Kolkata [5].

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Figure 1 exhibits the TL glow curves of the laboratory grown quartz crystal powder (230–325 mesh grain size in virgin form) without and with gamma irradiation [50, 100 and 200 Gy gamma doses]. It is clearly seen that without irradiation, the specimens do not display any TL (NTL).

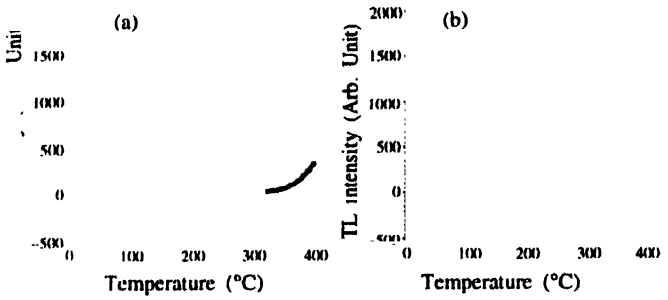

Figure 1(a,b). Thermoluminescence run for unirridiated virgin synthetic quartz (a) for virgin synthetic quartz (ooooo); (b) prethermally treated (at 100°C) synthetic quartz (——).

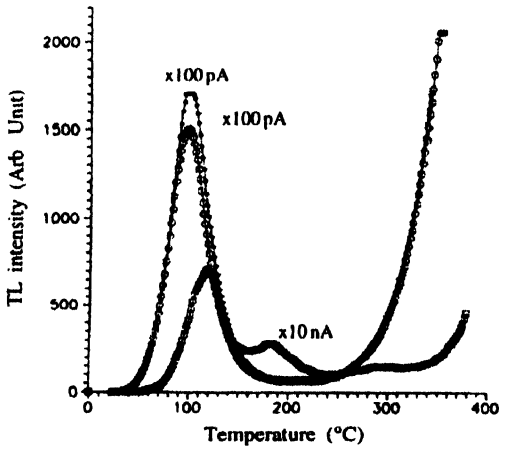

Figure 1(c). Thermoluminescence glow curve of synthetic quartz samples at various gamma doses. (1) 50 Gy (••••••); (2) 100 Gy (ooooo); (3) 200 Gy (ooooo).

The excitation with gamma radiation induces good radio-thermoluminescence (RTL). It is clearly seen that well-defined peak around 100°C appears at 50 Gy dose. The intensity of the peak is found decreasing for 100 Gy and then increasing for 200 Gy gamma dose along with shift in the peak position towards higher temperature side (90–140°C) [peak-I] on increasing the incident gamma dose. Besides this, another peak around 180°C appears which shifts towards higher temperature side and gets stabilized around 210°C [peak-II] with rise in the gamma dose. The intensity of peak-II is found growing with increase in the gamma dose. The Figure 1 indicates that the TL peaks are radiation induced one (RTL). Moreover, 210°C [peak-II] is sensitive to higher doses while peak-I is sensitive to lower doses. The peak-I has been examined in detail by many investigators in natural and synthetic quartz crystals and is established as good low-level dosimetry peak (doses up to 70 Gy) [6–9]. The attention has been paid to the systematic study of 210°C glow peak in synthetic quartz for high-level radiation dosimetry.

In order to achieve the same, TL of the present specimen after exposure to gamma radiation of different doses : 0.1, 1.0 and 5 kGy, have been examined under identical experimental conditions. The TL glow curves are presented in Figure 2. It is found that peak-I disappears and peak-II appears and grows in intensity with rise in gamma dose.

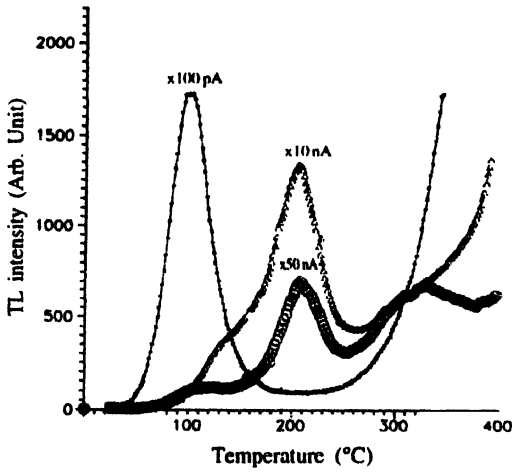

Figure 2. TL glow curve of synthetic quartz samples at three different gamma doses. (i) 0.1 kGy (••••••); (ii) 1.0 kGy (ΔΔΔΔΔΔ); (iii) 5.0 kGy (ooooo).

The peak at 325°C is also discernible in higher doses. The comparison of the TL glow curves with different gamma doses clearly indicates that the glow peaks observed in synthetic quartz are radiation-induced and dose-dependent The dose *versus* peak-II intensity response is presented in Figure 3. It clearly indicates that the TL-dose response is linear in the 100 Gy–2.5 kGy beyond which it is supralinear. This suggests that the present material will definitely be useful in the high-level-gamma radiation dosimetry provided

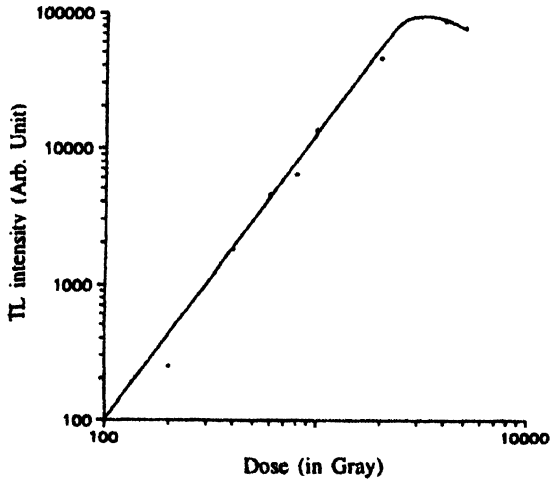

Figure 3. Dose *vs* TL response of virgin synthetic quartz samples.

it satisfies other basic requirements of an efficient TLD materials [10–12].

Other experimental results on the materials under investigation regarding emission spectrum, fading, photon energy dependence, desirable shape and size of dosimeter *etc.* have been carried out which strongly support that the present material would be very well suited for high level gamma radiation dosimetry.

It has been concluded from the TL glow curves of synthetic quartz material that the peak-II is sensitive to gamma dose and found giving linear response over the range 100 Gray–3.5 kGray beyond which it is supralinear. It is found that the present material under investigation will definitely be of use in the high level gamma radiation dosimetry required in the radiation processing.

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