Synthesis of Nanoparticles of Aluminium–Boron complex for Radiation Sensor

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Abstract

Radiation sensors based on thermo luminescence from nanoparticles of aluminium-boron complex for gamma radiation have been reported. Crystal chemistry of aluminium boride is quite complicated and is derived from complex tetragonal modification of boron. The crystal structure varies with the method of preparation and energy band gap contains defect states governed by the temperature during synthesis. There are various methods of preparing nanoparticles like boll milling, sol-gel and RF-thermal plasma. In the present studies Aluminum boron complex nanoparticles were synthesized by DC- transferred arc thermal plasma method. The DC-transferred arc thermal plasma has been received great attention as a useful method to synthesize nanoparticles. Since a substance is easily evaporated in large volume of thermal plasma. A pure aluminium and boron powders were mixed together and made to evaporate from water cooled graphite after impinging thermal plasma plume. Argon with flow rate of 3L/min was used as a plasma forming gas for the evaporation of raw powder mixture in Ar ambient in the plasma reactor. The obtained nanoparticles of aluminum –boron complex were characterized using X-ray diffraction technique for structural analysis, Transmission electron microscopy (TEM) for morphological analysis and energy dispersive analysis by X-ray (EDAX) for elemental analysis. The aluminum boron complex so obtained was investigated for thermoluminscence properties.

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1. Introduction:

Thermo luminescence is a well-established technique which is widely used for dosimetric applications and also for dating of the archeological samples [1]. It is one of the most important methods to reveal the surface states of the semiconductor materials which also provides the energy structure of the defect states. Recently nanoparticles of semiconducting materials have immerged as technologically important candidates for the application as radiation sensors [2]. This due to the increased surface to volume ratio which inturn increases the surface states [3]. The surface states are quite important in deciding the optical properties of semiconductors. There are reports [4] about the nanoparticles of the Mn and Cu doped ZnS as radiation sensors for detecting the radiation doses of gamma rays by thermo luminescence behavior. However the complete dosimetric applications have not been reported. The critical requirements of radiation dosimeter lies in the linearity of the TL intensity, efficiency to detect low doses, high saturation values, stable structure of the semiconductor and the repeatability of the material. Currently reports on TL properties have revealed that they include outstanding characteristics involving high sensitivity and linearity over a wide range of absorbed doses [5-9]. This behavior of nanoparticles has been accounted as a positive step for future radiation dosimetry in the medical and industrial applications. The paper represents a report on the experimental feasibility of using Al-B complex as a radiation sensor and for dosimetric applications. Aluminium borides form complicated structures and gets stabilized at high temperatures. It is a semiconducting material having band gap 1.2eV to 1.9eV. We have synthesized this complex from gas phase condensation using thermal plasma rout. After characterizing the material for knowing its crystalline structure, elemental purity and morphology it was subjected to thermo luminescence measurement. The traps have been filled by gamma irradiation using 60Co at different doses.

2. Experimental:

Nanoparticles of Al-B were synthesized by DC- transferred arc thermal plasma method. Pure aluminium and boron powders,mixed in required proportion,were used as initial ingredients. These ingredients were mixed uniformly, shaped into pellets and were kept onto the water cooled graphite electrode. Commercially available argon was made to flow through the plasma torch with the flow rate of 3L/min as a plasma forming gas for the evaporation of aluminum-boron mixed powder. In addition Ar was purged through the side port having flow rate of 5 L/min. The operating pressure inside the plasma reactor was maintained at 350 torr throughout the experiment. The plasma torch was operated at 3 kW DC power and was impinged onto aluminum-boron mixture for 3 -4 min to evaporate it from the anode. The evaporated powder was collected from theinner wall of the water cooled chamber. The powder so obtained was characterized by XRD using Bruker D8 advance X-ray Diffractometer, EDAX by SEM – JEOL JSM-6360A and TEM using TECHAI $G^2$20-TWIN (FEI, NETHERANDS). For TL measurement 20mg of the nano powders of Al-B complex were exposed to gammaradiations from ^{60}Co. The total dose of irradiation varied from 1Gy to 30kGy by varying exposer time at a dose rate of 1Gy/sec. The TL glow curves were recorded for 5mg of each sample for a constant heating rate of 50C/sec by TL – TLD Reader TL 1009 Nucleonix.

3. Results and discussion:

Fig.(1)shows the XRD pattern for Al-B complex nanophosphors. From XRD patterns four diffraction peaks were observed at 14.27^0, 27.54^0, 39.74^0 and 66.37^0. From the XRD pattern and by comparing with the JCPDS data it is observed that the complex consists of B_2O_3 (marked with ‘*’) and less crystalline structure of $AlB_{12}C_2$(marked with ‘o’) with peaks at 34.27^0, 37.25^0 and 62.62^0. The nature of crystalinity was consistent for repeated synthesis, carried out at identical conditions.

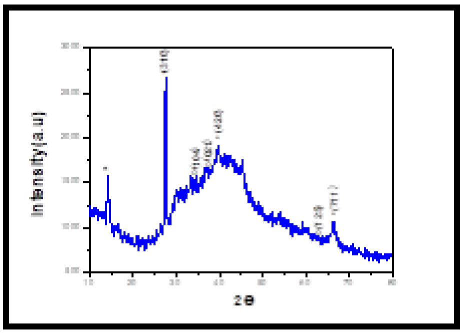

Fig. (1) XRD pattern of amorphous Al-B complex nanoparticles.

Fig. (2) Shows the EDAX spectra of aluminium boron based composites which suggest presence of aluminium, boron and carbon.

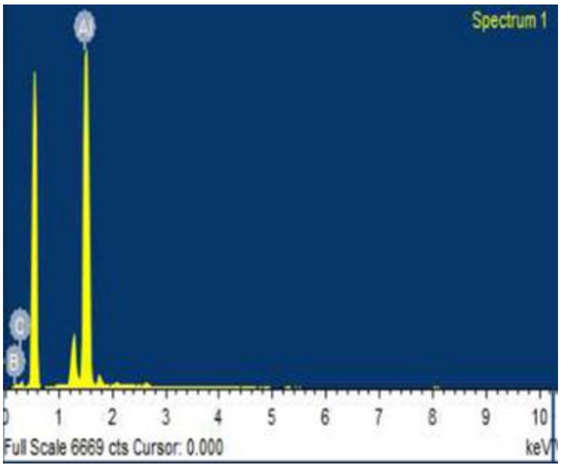

Fig. (2) EDS spectra of Al-B complex nanoparticles

Fig. (3) Shows the TEM image of the as synthesized nanoparticles of Al-B complex. It shows that the particles are spherical and the particle size varied in the range of 10nm to 80nm. The inset shows histogram of particles size. It is seen from Fig.4 that maximum number of particles possesses size in the range of 20 – 30 nm.

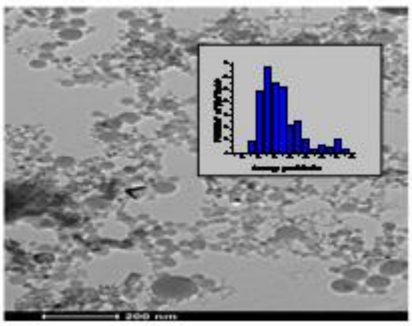

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Fig.(3) TEM image of Al-B complex nanoparticles.

Fig(4).shows thermo luminescenceresults of TL glow curve of aluminium-boron complex synthesized by DC- transferred arc thermal plasma technique. The TL properties of Al-B complex material have been investigated using TL glow curve and variation of sensitivity as a function of ^{60}Co gamma ray doses. TL glow curve showed main peak at 158 ^{0}C. This peak does not shift with increase in gamma ray dose. Further TL intensity linearly increases with increasing gamma dose at constant heating rate (5 ^{0}C/Sec). This increase in the TL glow curve peak is due to response of the trap sites which were initially formed during gamma irradiation. From TL glow curve we observed that there is no increase in intensity of peak ‘a’ at 1Gy, it indicates that there is no generation free electrons at this radiation doses. But after 1Gy the intensity of the peaks increases in peak ‘b’ and ‘c’ at 109^{0}C reaches its maximum value at 171^{0}C and again decreases at 363^{0}C. It indicates that there are more number of electrons get enough energy and fill the empty traps, while by increase in heating temperature these trapped electrons again detrapped and emit light or photons which is proportional to the previous gamma ray doses. At 235^{0}C we observe second peak it indicates presence of another trapping state.

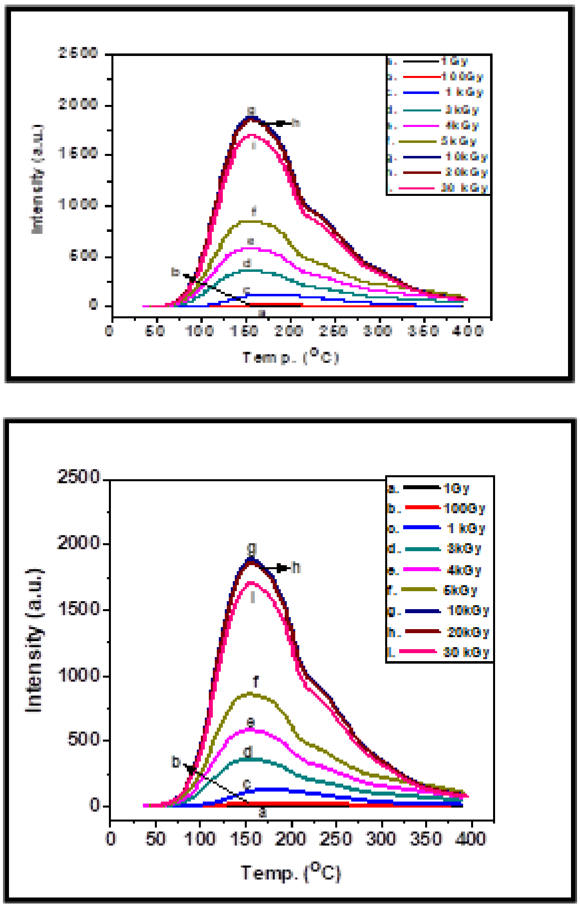

Fig.(4): TL spectra of Al-B based nanoparticles

To investigate the response curve of gamma ray irradiated aluminum boride complex, shown in fig.(5), the maximum TL intensity was noted for a given dose of gamma rays. It is clearly seen that, the absorbed dose show sub-linear response in the gamma ray dose in the range of 1 Gy to 100 Gy.

But interestingly, the gamma ray dose from 100 Gy to 10 kGy show sharp rise in TL intensity. However, above 10 kGy dose response gets saturated. The very sensitive linear response between 100 Gy to 10kGy can be effectively usedas gamma radiation dosimeters.

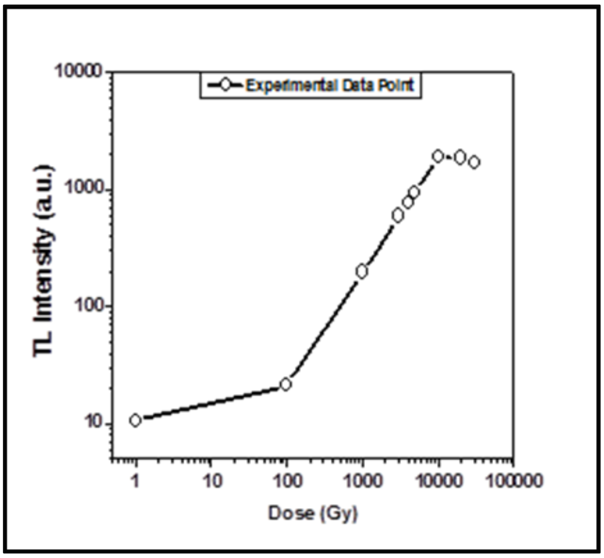

Fig.(5): TL Dose Response of Al-B basednanoparticles.

4.Conclusions:

We have synthesized Al-B complex phosphors by DC- transferred arc thermal plasma method. The thermoluminescence studies in Al-B complex phosphors irradiated with gamma rays are presented. The traps formed by gamma irradiation in nanoparticles are deeper than their bulk counterparts. TL glow curve showed main peak at 158 ^{0}C. This peak does not shift with increasein gamma ray dose. Further TL intensity linearly increases with increasing gamma dose at constant heating rate (5 ^{0}C/Sec). It also has a linear response to a wide range of gamma doses, making it quiet suitable for TL dosimetry.

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References

1. Peng, W.Q.; Cong, G.W.; Qu, S.C.; Wang, Z.G. Opt. Mater. **29**, 313,(2006).
2. Ravi Sharma, B.P.Chandra, D.P.Bisen; Chalcogenide Letters Vol. 6, June 2009, p. 251 – 255

3. Dhabliya, D. (2022). Audit of Apache Spark Engineering in Data Science and Examination of Its Functioning Component and Restrictions and Advantages. INTERNATIONAL JOURNAL OF MANAGEMENT AND ENGINEERING RESEARCH, 2(1), 01–04.
4. Dhabliya, D. (2021d). Examine Several Time Stamping Systems and Analyse their Advantages and Disadvantages. International Journal of Engineering Research, 1(2), 01–05.
5. Dhabliya, D., & Others. (2021). An Integrated Optimization Model for Plant Diseases Prediction with Machine Learning Model. Machine Learning Applications in Engineering Education and Management, 1(2), 21–26.
6. Bouvy, C.; Piret, F.; Marine, W.; Su, B.L. Chem. Phys. Lett.**433**, 350,(2007).
7. Ravi Sharma, B.P.Chandra, D.P.Bisen; Chalcogenide Letters Vol. 6, June 2009, p. 251 – 255
8. De la Rosa, E.; Rodrlguez, R.A.;Melendrez, R.; Salas, P.; Diaz-Torres, L.A.; Barboza Flores, M. Thermoluminescence properties of undoped and Tb3+And Ce3+ doped YAG nanophosphor underUV-, X- and B-ray irradiation. *Nucl. Instrum. Meth. Phys. Res.* **2007**, *255*, 357–364.
9. Kortov, V.S. Nanophosphors and outlooks for their use in ionizing radiation detection. *Radiat. Meas.* **2010**, *45*, 3–6.
10. Salah, N. Nanocrystalline materials for the dosimetry of heavy charged particles: A review. *Radiat. Phys. Chem.* **2011**, *80*, 1–10.
11. Salah, N.; Sahare, P.D.; Rupasov, A.A. Thermoluminescence of nanocrystalline LiF: Mg, Cu, P. *J. Lumin.* **2007**, *124*, 357–364.
12. Singh, L.; Chopra, V.; Lochab, S.P. Synthesis and characterization of thermoluminescent Li2B4O7 nanophosphor. *J. Lumin.* **2011**, *131*, 1177–1183