

## Mechanoluminescence of $\gamma$ -irradiated salt

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The dependence of mechanoluminescence (ML) intensity on  $\gamma$ -dose of irradiated salt has been studied. It is found that initially the ML intensity increases with increasing  $\gamma$ -dose given to the sample, attains an optimum value around  $3 \times 10^3$  Gy then decreases with further increase in  $\gamma$ -dose. The spectroscopic study of ML and the effect of optical bleaching and storage (fading) on ML intensity have also been investigated to understand the mechanism of ML excitation in household salt. The radiation-induced changes in food material might also be analyzed by studying their ML properties.

**Keywords:** Mechanoluminescence,  $\gamma$ -irradiation, Colour center

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### 1 Introduction

Radiation processing of food for preservation is one of the major applications for ionizing radiation to strengthen food safety and security. Radiation processing of food covers a wide range of doses (0.05-50 kGy) depending upon the commodity and objective of the treatment viz. sterilization, sprout inhibition or disinfestations. However, there is no visible or perceptible change in food processed by radiation and therefore it is difficult to detect by sensory means whether a food is radiation processed unless it is labeled so. There are methods (TL, ESR etc.) available for the identification of a range of irradiated food<sup>1,2</sup>.

Radiation causes excitation of molecules besides formation of free radicals. The presence of excited states can be discovered by measuring of light emission when food is heated (thermoluminescence), or stimulated by light (photoluminescence), or when dissolved in suitable solvent (lyoluminescence). The term mechanoluminescence (ML) has been used to describe whole variety of process in which light is emitted due to mechanical deformation of solid. The ML intensity of coloured alkali halide crystals and  $\text{CaSO}_4$ : Dy phosphor increases with-dose given to them<sup>3-5</sup>. The main aim of the present study is to see how the irradiation changes the ML properties of salt.

### 2 Materials and Methods

Household salt in the powder form was used in the present investigation. The  $\gamma$ -irradiation was carried out using a  $^{60}\text{Co}$  source having exposure rate of  $2.806 \times 10^3$  Gy/hr. The ML was excited impulsively using a technique in which a load of 0.3 kg was dropped onto the sample from a height of 0.3 m using a guiding cylinder. The luminescence was monitored by using a photomultiplier tube (RCA 931) connected to storage oscilloscope (Scientific HM 205). For recording ML spectra, filters of different wavelength were placed between sample holder (lucite plate) and PM tube.

### 3 Results and Discussion

Figure 1 shows the characteristics of ML induced by the impact of moving piston onto non-irradiated and irradiated salt samples. Only one peak is observed in the ML intensity versus time curve of non-irradiated sample, however, two distinct peaks are observed for irradiated samples. It is also noticed that the peak intensity of first and second peak (i.e.  $I_{m1}$  and  $I_{m2}$ ) increases with increasing  $\gamma$ -dose given to them.

Figure 2 shows the dependence of total ML intensity i.e. area below ML intensity versus time curve on  $\gamma$ -dose. It is clear that the total ML intensity initially increases with increasing irradiation doses

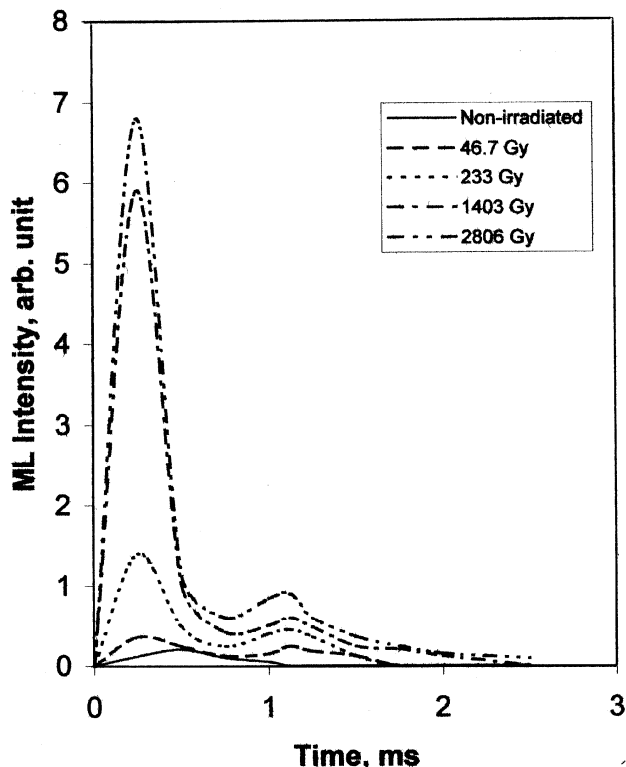


Fig. 1—Time dependence of the ML intensity of non-irradiated and  $\gamma$ -irradiated salt

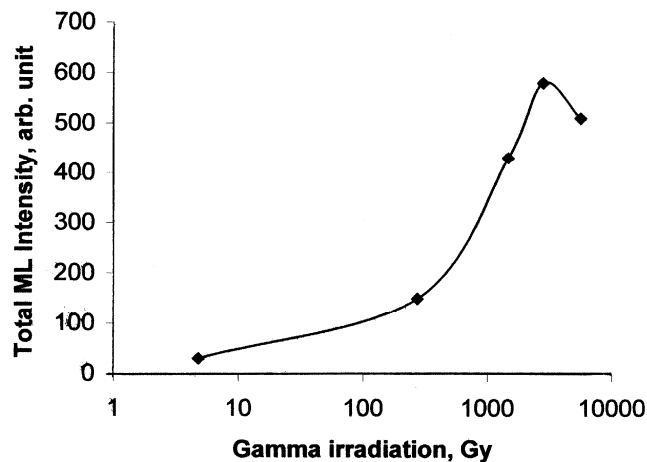


Fig. 2—Dependence of total ML intensity on  $\gamma$ -dose

given to sample, attains an optimum value around the dose level of  $2.806 \times 10^3$  Gy, then decreases with further increase in  $\gamma$ -irradiation. The shape of the ML glow curves is the same for salts of various brands, however, their relative ML intensity is different<sup>6</sup>. The main constituent of household salt is sodium chloride and we speculate that the variation in the ML intensity of salt sample of different brands attributed the

presence of different impurities in different concentrations.

Sodium chloride is an important member of alkali halide family. The deformation of alkali halide crystals is known to result in the colour center destruction. Luminescence associated with deformation of coloured (treated with radiation) crystals, indicative of colour center destruction was studied by a number of researchers<sup>7-10</sup>. However, the currently available experimental data are inadequate to identify the destroyed centers unambiguously. The ML is attributed to ionization of F and F aggregate centers by dislocation<sup>7,8</sup>, but some evidence is in conflict with this opinion<sup>9,10</sup>.

The mechanism of ML is not well established but it is accepted that the ML is associated with the release of trapped carriers from electronic defects by the movement of dislocations set in the motion by applied pressure. In non-irradiated salt sample (Fig. 1) only one peak is observed in the ML intensity versus time curve and the ML emission stops as soon as the deformation is interrupted. In the present study, for irradiated salt sample it was found that the ML emission occurs even after the deformation and in addition to the first peak, a second peak is observed in the ML intensity versus time curve. The occurrence of two peaks and enhancement of ML intensity with  $\gamma$ -irradiation indicate that different types of traps are involved in the ML excitation and density of these centers increases with increasing  $\gamma$ -dose given to them.

During the deformation of  $\gamma$ -irradiated salt sample, the moving dislocations interact mechanically with colour-center (F-center) and subsequently capture electrons from those nearby<sup>11</sup>. The captured electrons move with dislocations and they also move freely along the dislocation line at the same time. The dislocation electrons have a finite lifetime  $\tau_d$ . At  $\tau > \tau_d$ , they either recombine with the holes or are captured by other shallow traps in the sample. If the moving dislocations containing electrons encounter the defect centers containing hole, the dislocation electrons may be captured by these centers and luminescence may arise (first peak). The second peak, which occurs in the post deformation region, may be due to the capture of carriers by the shallow traps where field is not so effective. The release of trapped carriers from shallow traps may take place later on due to thermal vibration of lattices and therefore a delayed ML (second peak) may be produced.

On the basis of ML, thermoluminescence and luminescence spectra of coloured alkali halide crystals, Atari<sup>12</sup> and Chanrda<sup>11</sup> proposed that the ML emission in X- or  $\gamma$ -irradiated alkali halide crystal is due to the recombination of F-center electrons with  $V_2$  center. Thus, the energy corresponding to peak of ML spectra should reflect the energy difference between the bottom of conduction band  $E_C$  and energy level of the  $V_2$  center  $E_{V_2}$ . The calculated value of wavelength [ $\lambda_m = ch/(E_C - E_{V_2})$ ] corresponding to the peak of ML spectra for NaCl is 451 nm. However, in the present investigation, one sharp peak around 482 nm is observed in ML spectra. The total duration of ML output for irradiated salt sample is 2 to 3 milli sec which ruled out the possibility of using monochromator for recording ML spectra, hence, the difference in theoretical and experimental value of  $\lambda_m$  may occur because of limitations of our experimental set-up.

After exposure of a ML material to ionizing radiation, the latent measure of the observed dose is directly related to number of electrons, which remain trapped in the various trapping levels. Unintentional release of these electrons before read out, is called fading. Fading may be due to thermally or optically stimulated release of the electron or a combination of both. For considering the candidature of salt in radiation or retrospective dosimetry, it is necessary that the ML in the salt used is stable and does not decay upon storage under usual conditions. It is found that the fading in ML intensity is about 65% when the sample was deformed 10 days after  $\gamma$ -irradiation.

Fading of ML is not observed in alkali halide single crystals. Powder differs from the single crystal in two respects, they contain a large number of dislocations and possess high surface to volume ratio. The fading in ML intensity is due to loss of colouration in microcrystalline powder, which in turn is caused by interaction of mobile dislocation by colour centers. Fading in ML intensity also indicates that even at room temperature (i.e. temperature of storage), the carriers are thermally released from their trapping sites into delocalized bands, or any other excited state from where they may recombine either radiatively or non-radiatively with carriers of opposite sign in the recombination centers.

The observation of ML requires the mechanical stimulation of trapped charge carriers either into

delocalized energy bands or into higher excited states. In a similar fashion, the charge carrier stimulation can be achieved via the absorption of optical energy rather than mechanical energy. The ability to bleach trapped charge optically has an important influence on mechanoluminescence measurements. In order to know the effect of optical illumination on the ML of irradiated salt, the irradiated sample was exposed to sunlight for different duration before deforming the sample. We have found that the loss of ML intensity becomes 65% when the sample is exposed for 1 hr to direct sunlight. This fact indicates that the exposure of irradiated salt to sunlight gives rise to a reduction of the ML signal due to emptying of charge from the trap responsible for ML signal.

#### 4 Conclusions

The radiation induced changes in food material like salt can also be analyzed by studying their ML properties, and the household salt is not suitable for ML dosimetry because of poor exposure response, higher fading and optically sensitive properties, hence, ML of other food material like sugar, black pepper, turmeric, chili-powder may be studied for better results.

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