Thermoluminescence of Alkali Halides

G.Muralidharan

Department of Physics, Gandhigram Rural Institute, Gandhigram 624 302

muraligru@gmail.com

Alkali halides have been a subject of study for the past seven decades. They have lent a helping hand in understanding the physics of the solid state. The main attraction of the alkali halides is their crystal structure. All the alkali halides excepting cesium halides crystallize in the face centered cubic structure while cesium halides belong to the class of base centered cubic crystals. The alkali halides have a high melting point and are having large band gap from about 6 eV for RbI to about 10 eV for LiF. They have a wide range of lattice parameters, 7.34 Å for RbI to 4.03 Å for LiF, making them suitable for the incorporation of impurity ions of different sizes in their lattices. The alkali halides have a transparent window extending from the near IR to UV, permitting a wide range of defects and impurities to be studied in the visible and UV region. The impurity doped alkali halides are interesting for the pristine ones do not give much information. The impurity doping leads to many structural defects and colouration of the medium that the properties can be easily studied.

Luminescence is a phenomenon known as cool emission of light. When a material is excited with some stimulus, it responds by emission of light. Part of the energy goes as heat as well. The emission of radiation is known as luminescence. If the excitation is light, then the process is called as photoluminescence. Depending on the lifetime of the excited from where light is emitted, the process is called as fluorescence or phosphorescence. If the light emission ceases immediately on the stoppage of the exciting light, then it is fluorescence whereas if it continues after the excitation is removed, it is termed as phosphorescence.

Thermoluminescence (TL) is a misnomer. Here heat is only a stimulus and not the cause. Thermoluminescence is a process where light is emitted when a material that is previously exposed to ionizing radiation like UV, x-rays or gamma rays is heated. The phenomenon was first observed by Robert Boyle when he heated a piece of diamond in the dark.

The basic phenomenon behind TL is the creation of defects. Defects are thermodynamic necessity. There are defects such as vacancies, interstitials, foreign atoms and ions and trapped charges. When a material is exposed to ionizing radiation like gamma rays, photolysis of the medium takes place. This creates electron and hole pairs. The created electrons and holes are free to move around and when they encounter a trap of the opposite kind, they are trapped. For example in the case of sodium chloride, a chlorine ion vacancy effectively bears a positive charge and hence an electron can be trapped there. Such a defect is called an F centre. There are defects which trap a hole. These are mostly molecular centers like a $(Cl_2)^-$. There are other centers like perturbed F-centers called F_A and F_z centers and aggregates of F-centers like M, N and R centers. The prominent hole centers are V_K centers, and V centers. These centers can be studied via optical absorption. Such trapped charges absorb light in the visible region and can be monitored through optical absorption.

Thermolumenscence studies are made in two ways. One is observing the total light emitted by the material as it is heated at a constant rate against temperature. This is known as TL glow. Normally the TL glow consists of one or more peaks. It indicates the number of steps in which the trapped charges are annihilated. The other is looking at the spectral composition of the light emitted under each of the glow peak, called TL emission. The number of recombination sites is understood from the TL emission studies. This is recorded by keeping the sample at a constant temperature and scanning the light emitted with a monochromator.

The understanding of thermoluminescence is done using associated measurements like optical absorption, electron spin resonance, optically stimulated luminescence and laser Raman studies. The step wise annealing of defects has been correlated with the colour centers. There are two schools of thought on the process. One school prescribes that the thermally mobilized species are the holes and electrons act as recombination centers while the other group is of the opinion that the electrons are mobile entities.

This talk will discuss the basic processes like defect creation, its monitoring through optical absorption. The study of impurities and their modification on irradiation and optical treatment are done via absorption studies. There are excellent papers by Alveraez Rivas and his group on the step wise annealing of colour centers. The optically stimulated luminescence has thrown light on the recombination and thermally mobilized species. Recently we have incorporated trivalent terbium, samarium and cerium into potassium and rubidium halides. We could observe the emission of these rare earth ions in the TL emission and optically stimulated emission giving a strong indication that these ions are involved in the TL process. We have also observed stabilization of samarium in its divalent state when the crystal was irradiated with gamma rays. All these interesting aspects will be discussed in this paper.