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Mechanoluminescence characterization of CdS/ZnS doped PVDF nanocomposites

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Abstract:

This paper presents the in the field of mechanoluminescence (ML) for semiconducting sulfide-doped nanocomposites. ML is a phenomenon in which a material emits light when it is subjected to mechanical stress or deformation. In particular, CdS/ZnS-doped PVDF semiconducting sulfide-doped polymer nanocomposites have demonstrated considerable potential in various ML applications. This paper covers the synthesis, characterization, and ML mechanism of these nanocomposites, with a focus on the unique characteristics that render them suitable for ML applications.

Keywords: Mechanoluminescence (ML), Characterization, Nanocomposites.

Introduction:

Due to the widespread use of various types of lamps, TVs, mobile displays, LED lamps, LED TVs, signals, displays, etc., luminescence devices have become so fundamental to modern urban civilization that life cannot be imagined without them. Luminescence is "cold light, and it can happen at room temperature or lower [1-2]. Luminescence is the emission of cold light owing to different excitation sources, unlike the black-body radiation seen in incandescent lights. Mechanoluminescence is a general term used to describe the luminescence triggered by mechanical stimuli. The concept of triboluminescence was previously used interchangeably with ML, but now refers to luminescence resulting from the contact of two different materials. Depending on the level of applied stress, ML can be categorized as elasticoluminescence, plasticoluminescence, or fractoluminescence. It has been estimated that fractoluminescence can be found in approximately 36% of inorganic and even 50% of all crystalline materials and has been documented in up to 1,000 different compounds. Francis Bacon first mentioned this phenomenon in his book, “The Advancement of Learning (1605)”[3-7].

PVDF + CdS/ZnS nanocomposites possess various desirable properties that make them ideal for a range of technological applications. These include mechanoluminescence, which makes them useful for stress sensing and structural health monitoring; excellent optical properties such as high absorption coefficient and quantum efficiency, which make them suitable for use in solar cells, photodetectors, and light-emitting diodes; increased electrical conductivity, making them useful as electrodes in energy-storage devices; good thermal stability, allowing them to be used in high-temperature applications; and biocompatibility, which makes them promising materials for biomedical applications such as drug delivery and tissue engineering. Additionally, semiconducting sulfide-doped nanocomposites can be used in energy harvesting to convert mechanical energy into electrical energy, and in optoelectronics to develop innovative light-emitting devices[8-12].

Synthesis and Characterization:

To synthesize the materials in this study, all the necessary chemical reagents were obtained from HiMedia.The equipment used in the experiment included a magnetic stirrer, centrifuge, ultrasonic bath, and vacuum oven. These instruments were used to mix, separate, and dry the materials. The use of high-quality chemicals and reliable equipment ensured the accuracy and reproducibility of experimental results.

Synthesizing Sulphides Doped Nanocomposites:

Fig.1(a): synthesis of CdS NP's

Fig.1(b): synthesis of ZnS NP's

In this study, CdS and ZnS nanoparticles (NPs) were synthesized in fig 1 (a) & (b)) , using a chemical co-precipitation method and obtain purified CdS and ZnS NPs, the mixture was distilled with deionized water and ultracentrifuged for 10 min. The purified CdS NPs were then transferred to a petri dish and dried for 48 h. Polymer nanocomposites based on PVDF+CdS/ZnS were synthesized by dissolving 1 g of PVDF in dimethylformamide at 60°C. ZnS and CdS nanoparticles were added to the polymer solution at various weight contents and mixed for an hour until a homogeneous mixture was obtained. The mixture was then transferred to a petri dish and dried in an oven at 60°C[13].

Characterization of prepared NPs:

XRD Analysis

X-ray diffraction (XRD) analysis was conducted using a Rigaku Mini Flex 600 XRD diffractometer equipped with Cu Kα radiation at room temperature. The PXRD pattern of ZnS nanoparticles revealed broad intense peaks at 2θ values of 29.02°, 48.25°, 56.94°, and low intense sharp at 32.17°, which correspond to the (111), (220), (311), and (200) planes of a cubic unit cell of ZnS with space group F-43m (ICDD card no: 00-001-0792). In contrast, CdS nanoparticles exhibited diffraction peaks at 2θ values of 24.62°, 26.59°, 30.48°, 36.62°, 44.07°, 48.4°, and 52.19°, which correspond to the (100), (002), (101), (102), (110), and (112) planes of a hexagonal unit cell of CdS nanoparticles with P6 3 mc space group (ICDD card no: 00-002-0549) have shown in the figure.

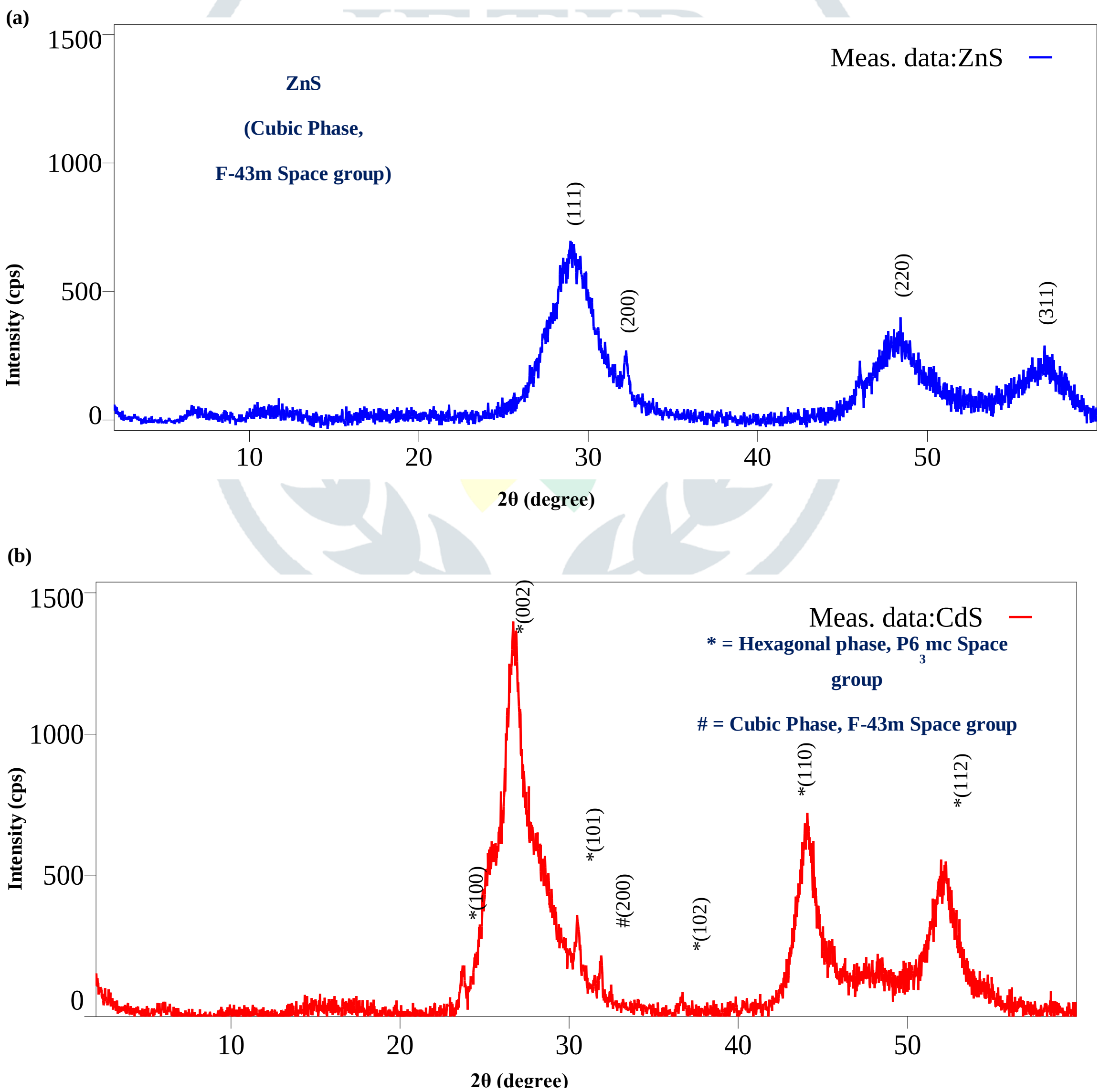

Fig.2(a) & (b) : XRD ananlysis of CdS & ZnS NP’s

ML Mechanisms:

The mechanoluminescence (ML) apparatus utilizes a mechanical load generator, a light measurement system, and a data acquisition system. The sample was inserted into the apparatus and subjected to a specific amount of mechanical stress using the load generator. The light emitted from the sample is detected by a light measurement system, which may consist of a photomultiplier tube, spectrometer, or CCD camera[14]. The intensity of the light emission is then recorded by the data acquisition system, which correlates the light emission with the applied mechanical stress. The ML mechanism of semiconducting sulphides doped nanocomposites is complex and involves various physical and chemical processes. One of the main mechanisms is the piezoelectric effect, which involves the generation of an electrical field owing to mechanical stress or deformation of a material. This effect can generate ML in materials with high dielectric constants. Other mechanisms include photon-induced ionization and defect-related and recombination-induced ML effects. These mechanisms involve the generation of free charge carriers and recombining electrons and holes, leading to ML emission.

ML Characterization of prepared samples:

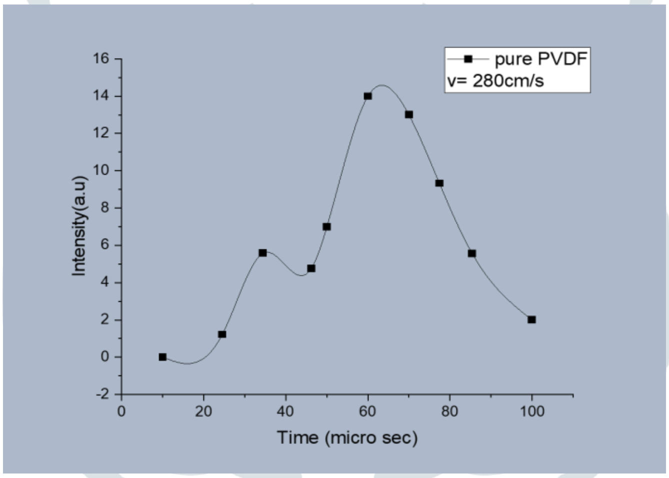

Fig. 3(a): ML analysis of pure PVDF

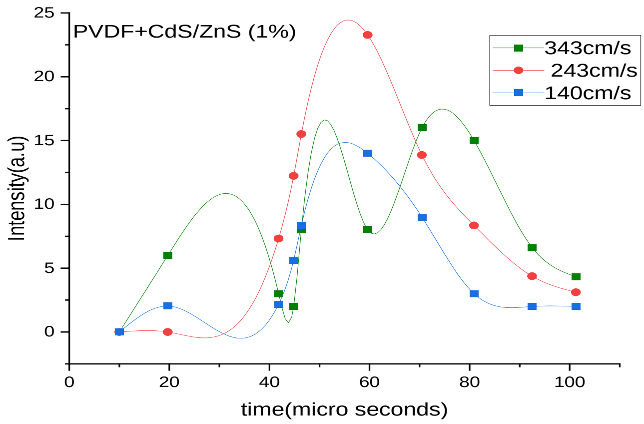

Fig. 3 (b): ML analysis of 1% concentration

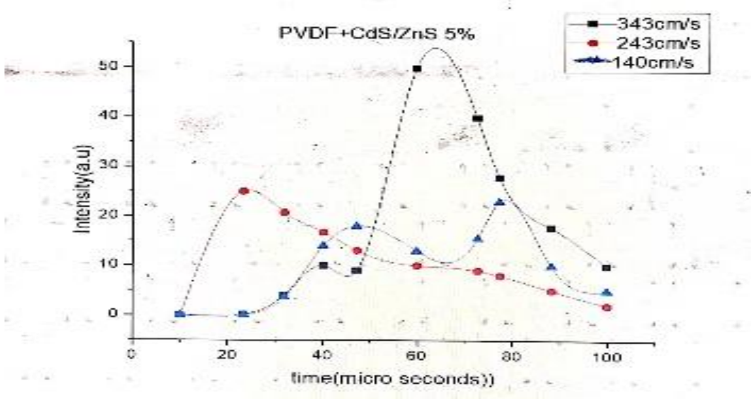

Fig. 3 (c): ML analysis of 5 % concentration

The ML intensities of undoped PVDF and CdS/ZnS doped PVDF nanocomposites (1wt% and 5wt%) were studied, and their time dependence curves were plotted, as shown in Fig. 3(a), (b), and (c). All the curves exhibited a similar trend of increasing intensity with time, followed by a peak, and then a gradual decrease. PVDF (undoped) showed a single peak only at 280 cm/s impact velocity, while the PVDF+ CdS/ZnS(doped) nanocomposites showed two peaks with a small shoulder. The decrease in intensity after a certain impact velocity could be attributed to the presence of different trapping levels and piezoelectric electrification, which may have influenced the ML analysis.

Conclusion:

Semiconducting sulphide-doped nanocomposites have shown promising advances in the field of mechanoluminescence. These materials exhibit excellent optical and electronic properties, high photoelectric conversion efficiency, and high stability. They have been synthesized using various methods and characterized using various techniques, revealing their unique properties. Furthermore, these materials have potential applications in various fields, including structural health monitoring, energy harvesting, and sensor technologies [15].

From fig 3 (a),(b) & (c), it is concluded that when PVDF is doped with semiconducting materials like CdS and ZnS ,then mechanoluminescence intensity is found to increase as compared to the undoped polymer film. It has been also found that ML intensity increases with rise in impact velocity on to the sample. This outcome is very interesting and makes the present nanocomposite a potential candidate for stress sensors. It may also play a vital role in imaging technology. Movement of micro dislocations, cleavage electrification, electron-hole recombinations may be responsible for ML emission in PVDF+CdS/ZnS nanocomposites.

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