Mechanoluminescence in Organic Crystalline Solid

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Abstract

Mechanoluminescence (ML) is the phenomenon of emission of light by the mechanical deformation of solids. The light emissions induced by elastic deformation, plastic deformation and fracture of solids are known as elastico ML plastico ML and fracto ML, respectively. ML produced during the fracture is called fracto mechanoluminescence. Initially, fracture was used as a tool to induced ML, but now days ,it is used to study the fracture of solid. When the crystal is fractured by loading ,then the time duration tc of the ML emission increases with increasing value of the applied load and the average value of the ML intensity from a single ML pulse decreases with increasing value of the applied load.

KEYWORDS: Luminescence, Mechanoluminescence, Fracture

1.Introduction

The Mechanoluminescence produced during the fracture is called fracto mechanoluminescence. Initially, fracture was used as a tool to induced ML, but now days ,it is used to study the fracture of solids .The ML technique makes possible the real-time monitoring of crack growth in solid, severity and location of damage, and the stress distribution near the tip of crack in solids.The fracto ML provides a self-indicating method of monitoring the microscopic and macroscopic process occurring during fracture of solids and gives important information related to the initiation,progation and interation of cracks in solids in microsecond and nanosecond scales.Rapid photographic method and CCD cameras have been used effectively to photograph the active areas of the crystals by their own light arising due to ML.The fracto ML also provide the online monitoring of grinding process in milling machines. Consequently ,the ML technique is attracting the interest of many worker for fracture studies. Moreover, the emission of intense light during the earthquake and mine-failure has also created the curiosity for the studies of ML produced during fracture of solids. More often, fracture occur during the application of loads on solids. Therefore it will be interesting to study the fracture ML of solids induced by the loading. The present paper reports the theory of the ML produced due to the fracture produced during the application loads on crystals and makes a comparison between the theoretical and experimental results. It is shown that the ML provides a tool for the real-time monitoring of cracks produced during the application of loading crystals. The crack propagation in dielectric solids connected with many structral and electronic excitation processes have been studied (1). It has been reported that, the ML provides a sensitive tool for the fracture studies in solids using the time-resolved ML(2).It has shown that initially the crack velocity increases with increasing length of the cracks.

Most experimental fracture analyses on structure ceramics have been implemented under conditions of quasi-static crack propagation. The traveling optics microscope technique and the loading-unloading technique have been widely utilized to detect stationary cracks under quasi statistic conditions, thereby obtaining crack lengths for conventional R-curve measurements. (3,4,5,6) . ML technique that can visualize macroscale crack propagation in realistic fracture regime wherein the crack speed is sufficiently high to simulate a conventional catastropic failure that occurs in actual application. (the so-called quasi-dynamic condition).(7,8,9)

2. Experimental

Since the ML intensity is very weak the crystal has to be near the photomultiplier tube without any risk of damage or disturbance to the photomultiplier tube setting when the pressure is applied or withdrawn .The photomultiplier tube housing and the crystal mouning plateform used in the present investigation. A solid teak wood block of size of 4”*4”*3” was taken .A cavity of the size of the diameter of the photomultiplier tube was made on the side surface for the “side on” alignment ,since the IP 28 tube is of “side on” type. A shielding metal cylinder, having a window, was put in the wooden cavity. It served two purpose ,first ,it provided shielding for stray voltage and second, it alsocavity provide safty to the window of the photomultiplier tube. A cavity was made on the top of the block to place a transparent Lucite or glass plate. The thickness of the Lucite plate and the glass plate. The was so chosen that the absorption of ML emission was as small as possible and it was sufficiently strong to endure the mechanical pressure applied on the crystal placed on it.

A uniaxial pressure was applied on the specimen by placing heavy load with almost zero velocity.The output of the photomultiplier tube was recorded using storage oscilloscope .The PMT housing used for the measurement.

3. Results

Fig:1 shows the plot between total number of cracks the total number of ML pulses increases with increasing value of the load

Fig. 2 shows the dependence of total ML intensity on the volume of the crystals. It is seen that for a given pressure, the total ML intensity increases linearly with the volume of the crystals.

Fig. 3 shows that the time duration t_c of the ML emission increases with increasing value of the applied load and the average value of the ML intensity from a single ML pulse decreases with increasing value of the applied.

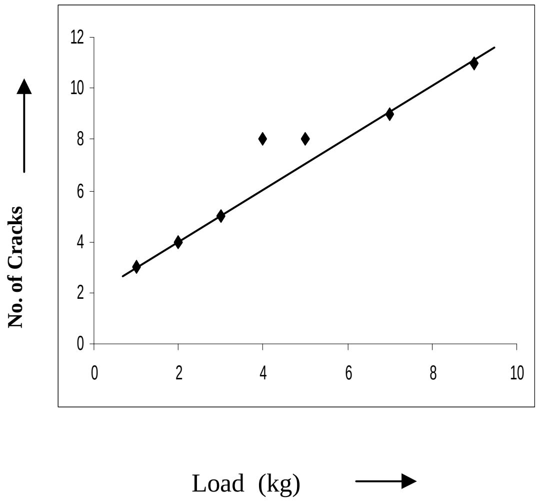

Fig. 1: Dependence of total number of cracks or total number of ML pulses on the load

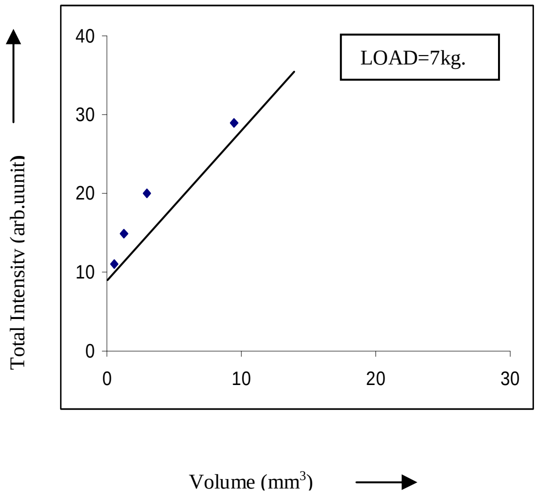

Fig:2 Dependence of total ML intensity on the volume of crystal

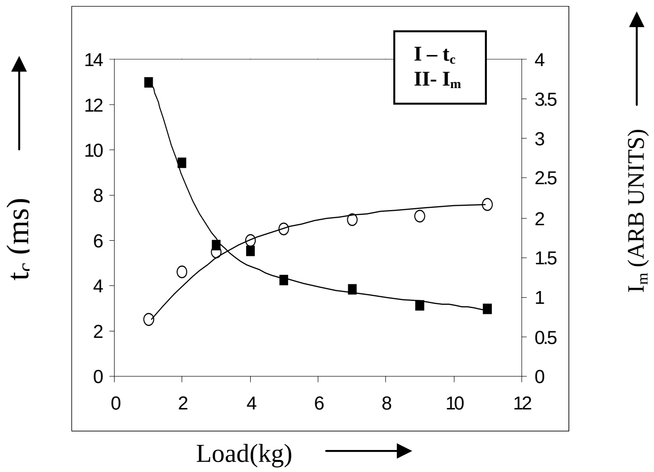

Fig. 3 : Dependence of t_c and I_m on the applied load on crystal .

4. Discussion

As cinchonine sulphate crystals have P_{21} P_{21} P_{21} (16) space group and P_1 space group (17) respectively, they are non-centrosymmetric and they exhibit the phenomenon of ML because of the charged surface produced during their fracture.

The piezoelectric origin of ML in non-centrosymmetric crystals; may be understood in the following way :

(i) Generally, the crystals exhibiting ML belong to twenty non-centrrosymmetric (piezoelectric) point groups and the crystals belonging to centrosymmetric (non-piezoelectric) point group do not exhibit ML. In organic crystals the newly created surfaces may get charged by the piezoelectrification as well as by other mechanisms, hence, the correlation between the ML and piezoelectric behaviour does not hold as satisfactory as in the case of organic crystals. There are some exceptions, that is, certain non-piezoelectric crystals, such as chemically impure saccharin, salicylamide, phthalic acid, etc. exhibit ML, but these crystals do not show ML after their purification. The ML of such impure crystals may be due to presenceof piezoelectric phase near the defects.

(ii) The ML has been measures in many polymorphic crystals, e.g. anthrasnilic acid, hexacarbodiphosphorane, acetamide, glycine, p-mannitol, p-antisidine etc. and it is has been found that ony the piezoelectric forms exhibit ML and the other forms do not.

(iii) Certain crystals, e.g. sugar, tartaric acid, ethylene diamine tartarate, etc. do not show ML when they are cleaved in a plane paralled to their pyroelectric axis, although ML is produced from all other cleavage planes.

(iv) Near the curie temperature of ferroelectric crystals, where the crystal structure transforms from one phase to another, a drastic change in the ML intensity takes place.

The ML excitation in piezoelectric crystals can be understood on the basis of the piezoelectrification of newly creates surfaces of crystals. When as stress is applied to a piezoelectric crystal, its one surface get positively charged and the opposite surface gets negatively charged. Due to the movement of crack in the crystal, new surfaces are created. The newly created surface nearer gets negatively charged. Thus an intense electric field may be produced between the newly created oppositely charged surfaces of crystal.

Cinchonie Sulphate is piezoelectric and their ML emission may be due to the discharge of surrounding gases During the fracture of a piezoelectric crystals an intense electric field of the order of 10^6 V/cm. is produced which produced gas discharge in the surrounding gases. However cinchonine sulphate crystals are fluorescent. In cinchonine sulphate crystals the ML emission resembling solid state luminescence may be possible.

5.Conclusions

The important conclusions drawn form the present investigation are given below :

(i) When a load is applied on a crystals, then the ML emission takes place in the form of light pulses.

(ii) The number of ML pulses increases with increasing value of load and the average ML intensity per ML pulses decreases with increasing value of the load.

(iii) Initially the total ML intensity increases with increase value of the load and then it tends to attain a saturation value for higher values of the load.

(iv) With increasing size of the crystals, the number of ML pulses increases and the time duration of ML increases, and therefore, the total ML intensity increases with increasing size of the crystals.

(v) The ML emission in cinchonine sulphate crystals in causes by gas discharge produced during the piezoelectrification of newly created surface produced during the fracture of crystals, however, the ML in cinchonine sulphate crystals is caused by the gas discharge as well as the radioactive electron-hole re-combination and the PL excitation by the gas discharge arising due to the piezoelectrification of the newly created surfaces.

(vi) The total ML intensity is directly related with the area of newly created surfaces. Therefore the pressure dependence of the total ML intensity indicates that initially the total area of newly created surfaces increases with increasing value the applied .

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