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# Mechanoluminescence—a sensitive tool to determine the strain dependence of newly created surfaces of crystals

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**Abstract** : When a crystal is deformed slowly, the mechanoluminescence (ML) appears, concurrently during the steps occurring in the stress-strain curves of the crystals, that is, during fracture of crystals. The total ML intensity is directly proportional to the compressive strain of the crystals and it is also linearly related with the area of newly created surfaces of the crystals. It is shown that the ML measurement, provides a sensitive tool to determine the strain dependence of newly created surfaces of crystals.

**Keywords** : Mechanoluminescence, stress-strain curve

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After a particular level, the applied load on to a solid cannot be balanced by an increase in the potential energy of the interatomic bonds. Therefore, the system becomes unstable whereby the increase in potential energy takes place by the movement of a crack, that is, by the creation of new surfaces. Thus, beyond a particular strain during the course of compressive deformation, a brittle solid changes frequently from mechanically unstable state to a stable state by the creation of new surfaces. As a matter of the fact, the area of newly created surfaces increases with the compressive strain of the crystals. The relationship between the area of newly created surfaces and strain of solids may find applications in several scientific investigations where the newly created surfaces of the fractured object may tell about the stress and strain at the instant of fracture. The present paper reports that the mechanoluminescence (ML) measurement provides a sensitive tool for determining the dependence of the area of newly created surfaces on the compressive strain of crystals.

Figure 1 shows the ML intensity *versus* strain; and stress *versus* strain curves of $6 \times 5 \times 4$ mm$^3$ triphenylamine and $6 \times 5 \times 3$ mm$^3$ phenanthrene single crystals. It is seen

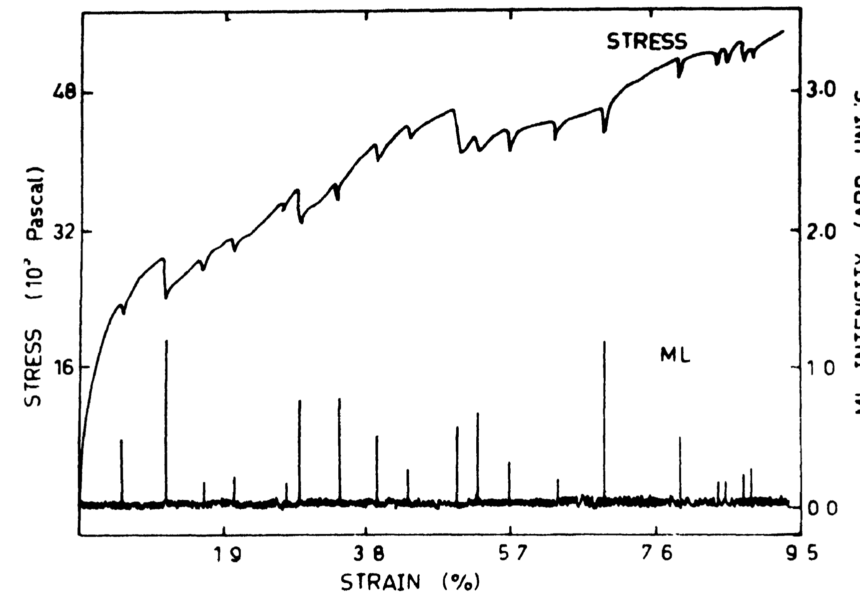


**Figure 1(a).** ML intensity *versus* strain and stress *versus* strain curves of $6 \times 5 \times 4$ mm$^3$ triphenylamine single crystals (rate of compression = $1.69 \times 10^{-3}$ mm $S^{-1}$)

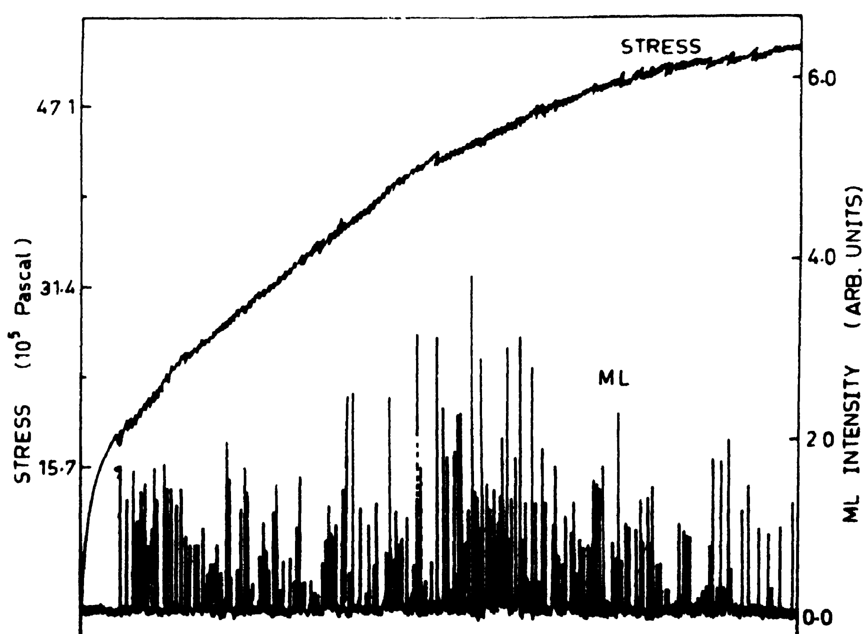


**Figure 1(b).** ML intensity *versus* strain and stress *versus* strain curves of $6 \times 4 \times 3$ mm$^3$ phenanthrene single crystals (rate of compression = $1.69 \times 10^{-3}$ mm s$^{-1}$).

that the ML appears concurrently with the steps occurring in the stress-strain curves of the crystals. It is evident from Figure 1 that in triphenylamine crystal, the sudden change in stress takes place at some particular value of strain which is followed by the emission of a ML pulse. Whereas in phenanthrene crystal, after the fracture stress, the value of stress fluctuates continuously and a large number of ML pulses appear during the deformation. It is found that after the fracture stress, small cracks are developed in phenanthrene crystals more frequently and thereby the more number of ML pulses appears during the deformation. The ML-strain curves of saccharin and cinchonine sulphate dihydrate crystals are found to be similar to that of phenanthrene crystals. The ML-strain curves of sucrose, tartaric acid, rochelle salt, uranyl nitrate hexahydrate, sodium chloride, lithium fluoride, lithium sulphate monohydrate, copper sulphate pentahydrate and silicon carbide crystals are found to be similar to that of triphenylamine crystals.

Figure 2 shows that the plot of log ($\Sigma I$) *versus* log of strain ($\varepsilon$) is a straight line with a positive slope (where $\Sigma I = I_T$, is the sum of total light emitted). The values of the slope are

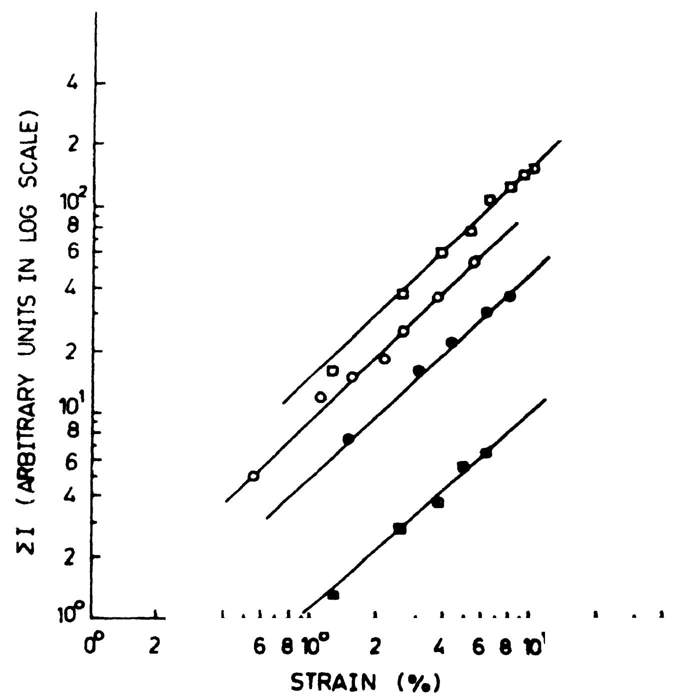


**Figure 2.** Plot of log ($\Sigma I$) *versus* strain log ($\varepsilon$) (Symbols O, ●, □ and ■ correspond to tartaric acid, triphenylamine, phenanthrene and uranyl nitrate hexahydrate crystals, respectively).

found to be 1.02, 1.03, 1.10 and 1.04, for tartaric acid, triphenylamine, phenanthrene and uranylnitrate hexahydrate crystals, respectively. It is known that tartaric acid crystals show gaseous discharge ML, triphenylamine and phenanthrene crystals exhibit the solid state

ML and uranyl-nitrate hexahydrate crystals exhibit the superimposition of gaseous discharge and solid state ML [1–5]. The crystals of tartaric acid and uranylnitrate hexahydrate were grown from the slow evaporation of their aqueous solution. Triphenylamine crystals were grown from the slow evaporation of their solution in acetone. The phenanthrene crystals were grown using Bridgman technique. The simultaneous measurement of the ML intensity *versus* strain and stress *versus* strain curves were carried out by the method described previously where Instron testing machine was used [6].

Figure 3 shows that the total ML intensity $I_T$ is directly proportional to the area of newly created surfaces of crystals. In this case, a crystal was cleaved near a photomultiplier

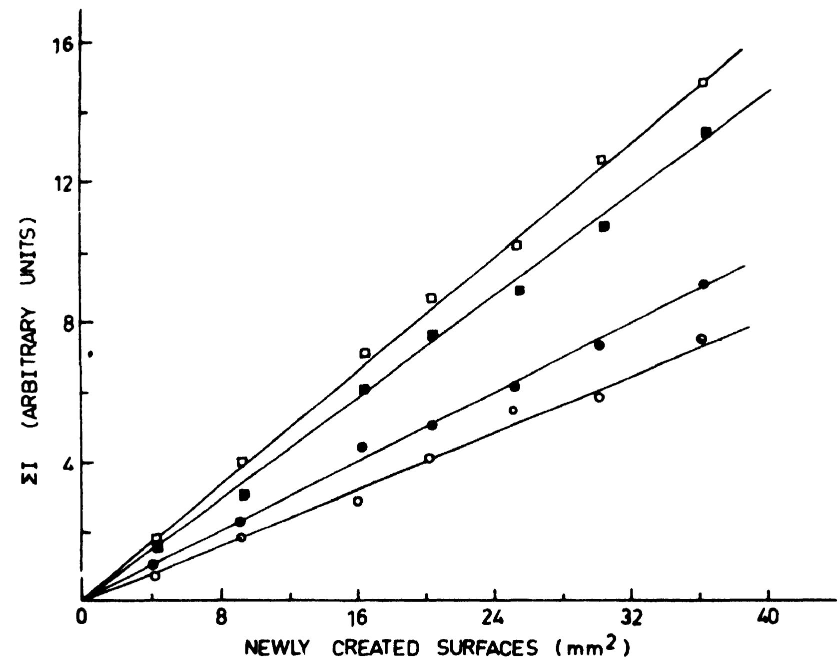


**Figure 3.** Dependence of the total ML intensity on the area of newly created surfaces (Symbols ○, ●, □ and ■ correspond to tartaric acid, triphenylamine, phenanthrene and uranyl nitrate hexahydrate crystals, respectively)

tube and the ML intensity was determined using an RCA 931 A photomultiplier tube connected to a Tektronix 564 dual beam storage oscilloscope. The area of newly created surfaces was determined from the known dimension of the crystals.

Since the intensity of ML is directly proportional to the area of newly created surfaces (Figure 3), the linear relation between $\Sigma I$ (or $I_T$) and $\varepsilon$, shows that the area of newly created surfaces is directly proportional to the compressive strain of crystals. Thus, the ML measurement provides a sensitive tool for determining the dependence of the area of newly created surfaces on the compressive strain of crystals.

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