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Prolonged Luminescence Induced by Grinding of Clays and Clay Materials

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The present paper reports the prolonged mechanoluminescence(ML) by grinding of clays and clay materials.

Fig.1 shows the decay curves of the ML of two types of kaolinites [1]. Grinding of the well-crystallized kaolinite (KGa-1) resulted in a higher photon-emission rate than that of the poorly crystallized kaolinite (KGa-2). The count rate of the latter did not appreciably increase with further grinding. The light emission after grinding of the samples continued for at least three days, and were very similar to those described by Stranski et al. [2] for arsenic crystals. A rough estimate of the ML at the very first moments can be made by intrapolating the curves in Fig.1 back to time zero. It is estimated that the count rate of the well-crystallized kaolinite immediately after the grinding was of the order of several million counts per minute. Fig.2 shows the decay curves of freshly filed-cube-like chunks of Mesa Alta kaolinite and umiat bentonite. The activity of kaolinite, which greatly exceeds that of bentonite, exhibits a similar decay characteristic ,where the decay was very fast during the first few minutes followed by a slower rate, whereby the slower rate gives a straight line on a log-log scale (Fig. 2). Considering the counting efficiency, it is estimated that the total amount of light emitted from a unit surface area of the Mesa Alta kaolinite, i.e. the light that was detected and counted by the scintillation spectrometer, was of the order of several tens of billions of photons per square centimeter of surface area. Obviously, part of the emitted light came from the surface, but the remainder originated at deeper layer in the solid phase. Thus, the total photon output of a unit mass of clay could not be estimated. Adding water to either the kaolinite or bentonite preparations increased somewhat the count rate of emitted light. No effort was made to quantify this effect. When freshly filed chunks of Mesa Alta kaolinite were dipped into a solution of the amino acid tryptophan and carefully drained, the count rate increased above that of same kaolinite chunk wetted with water. Though the increased count rate induced by tryptophan was significant, it could not be quantitatively measured [1].

The lifetime of the ML of quartz has not been determined in air. With vacuum cleavage, the lifetimes of 0.2 μs or less, 0.4 μs, about 100 ms and 1s have been found depending on the time frame examined. Grinding gives a lifetime of 400 hours [1]. The grinding-induced emission is thought to be primarily form quartz and its ML in vacuum consisted of millisecond bursts decaying with lifetimes of 2ms, 60 ms and 4s . The long lifetime of earth-quake lights is probably caused by continued propagation of cracks through rocks during an earthquake, rather than slow relaxation processes within one crystal. However, long -lived ML from defects created by extensive grinding may contribute to the observed lifetime. The long long lifetime of the ML induced by kaolinite in air is about 8 hours and

that of calcite is hundreds of hours[2]. In fact, the grinding -induced prolonged ML of solids may be attributed to the defects created by grinding.

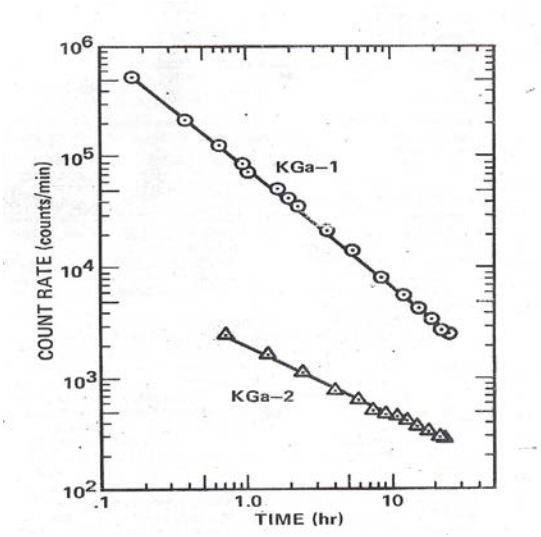

Fig. 1: Luminescence rate as a function of time elapsed from the end of grinding of well – crystallized kaolin KGa-1 and poorly crystallized kaolin KGa-2 (after ref. [1]).

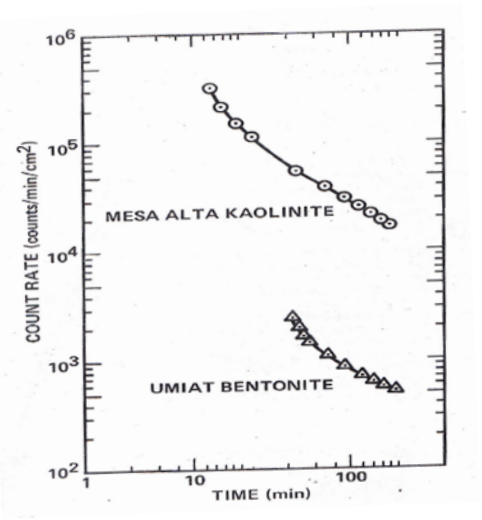

Fig. 2: Luminescence rate as a function of time elapsed from the end of filing of kaolinite (Mesa Alta, New Mexico) and bentonite, (Umiat, Alaska) (after ref. [1]).

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Considering that the distribution of traps at different depths is not uniform, an expression is derived for the time dependence of the prolonged ML intensity,and it can be expressed as

$$I = \eta n_0 kT\, t^{-\alpha} \qquad (1)$$

where η is the luminescence efficiency, n_0 is the total number of trapped charge carriers, k is the Boltzmann's constant, T is the absolutetemperature, t is time after grinding was stopped, and α is the decay constant.

Conclusively, a good agreement is found between the experimental and theoretical results.

References

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