APPLICATION OF A SPATIAL DISTRIBUTION READOUT SYSTEM OF THERMOLUMINESCENCE TO METEORITES

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Abstract: A spatial distribution readout system of thermoluminescence (TL) was recently developed. Spatial distribution of natural TL near fusion crust (MET-78028(L6)) and glow curve of each chondrule (ALH-77278(LL3) and ALH-77294(H5)) were measured using this system. More, TL emission spectra of a meteorite (MET-78028(L6)) were measured by replacing the objective camera lens by a spectroscope in this system.

1. Introduction

The thermoluminescence (TL) is normally observed under a photomultiplier (P.M.) by heating a material (AITKEN, 1974; FLEMING, 1979). This method measures the total integrated light, emitted over an acceptance angle of the P.M. Since this method measures TL of powdered materials or separated minerals, it provides no information on the spatial distribution of TL in inhomogeneous materials without separation of minerals.

Up to now, one searches the terrestrial age of meteorite (SEARS and DURRANI, 1980; MELCHER, 1981; NINAGAWA *et al.*, 1983) or classifies the petrological type of chondrites (SEARS *et al.*, 1980) by TL technique with P.M.

Recently, we have developed a spatial distribution readout system (I.I. and video system) of weak TL emission, consisting mainly of a high-gain image intensifier (I.I.), a TV camera and a video image processor (IMAEDA *et al.*, 1985). The system has been applied to the study of meteorites without destruction and/or separation of minerals. A similar TL system with a high-gain image intensifier and a photographic camera has been developed at Oxford University for archaeological and geological TL dating (WALTON and DEBENHAM, 1980; WALTON, 1982).

This time, by using the I.I. and video system we studied the TL emission spectra (MET-78028(L6)), spatial distribution of natural TL near fusion crust (MET-78028(L6)) and each glow curve of chondrules (ALH-77278(LL3) and ALH-77294(H5)).

2. Experimental Apparatus

The spatial distribution readout system of TL is shown in Fig. 1. This system consists of a) a heater, b) an image intensifier (2-D photon counting tube), c) a CCD TV camera, d) a video cassette recorder, e) a video image processor and f) a host computer.

The samples are placed on a heater plate in an oven which is filled with nitrogen gas and are heated at a rate of 2.3°C/s. The thermocouple is used to measure surface temperature of the heater plate. An optical image (photons emitted from the sample) is focused on a photocathode (multialkali (280–750 nm)) of the I.I. by camera lens. Electrons emitted from the photocathode are accelerated and multiplied by two stages of micro-channel-plates. These multiplied electrons are focused on the phosphor screen (P-20), and then an optical image consisting of discrete spots is reproduced. The time-varying image is taken by a CCD TV camera and is once recorded by a video cassette recorder as frame pictures. These frame pictures can be reproduced any time by the video cassette recorder.

Frame signals are converted to 8-bits digital data by a fast analog-digital-converter of the video image processor. The 8-bits digital data are accumulated on the video image processor memory (512×512×16 bits) corresponding to pixcels (512×512) of a frame. The frame signals can be accumulated at any time and for any intervals. The data of frame memory can be transmitted to a host computer through interface

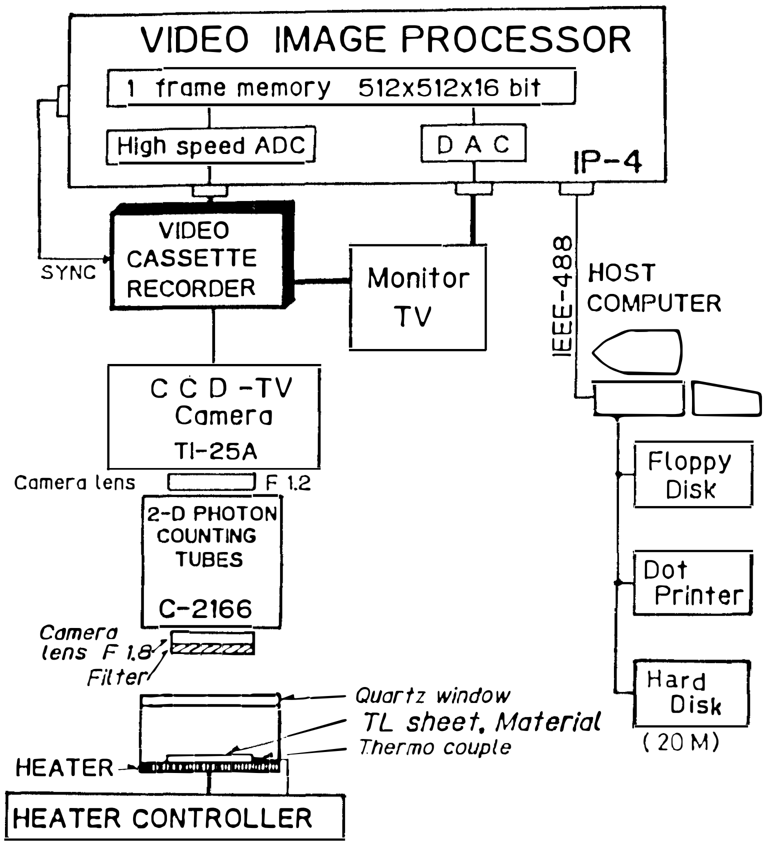

Fig. 1. spatial distribution readout system of thermoluminescence.

GP-IB, stored on floppy disks and processed by the host computer.

3. TL Emission Spectra

The sample, MET-78028(L6), was gently powdered in a mortar. Then this sample was irradiated with X-ray (about 10^5 R) after annealing. To measure TL emission spectra, the objective camera lens was replaced by a spectroscope (F: 3.5, grating constant: 3.3 μm, blaze wavelength: 500 nm) in this system. TL emission spectra of MET-78028(L6) are shown in Fig. 2. The half breadth at 436 nm was 8 nm in this measurement. TL of the meteorite has a wide spectral band with a maximum at ~450 nm. This spectrum shows that of feldspar (AKBER and PRESCOTT, 1985).

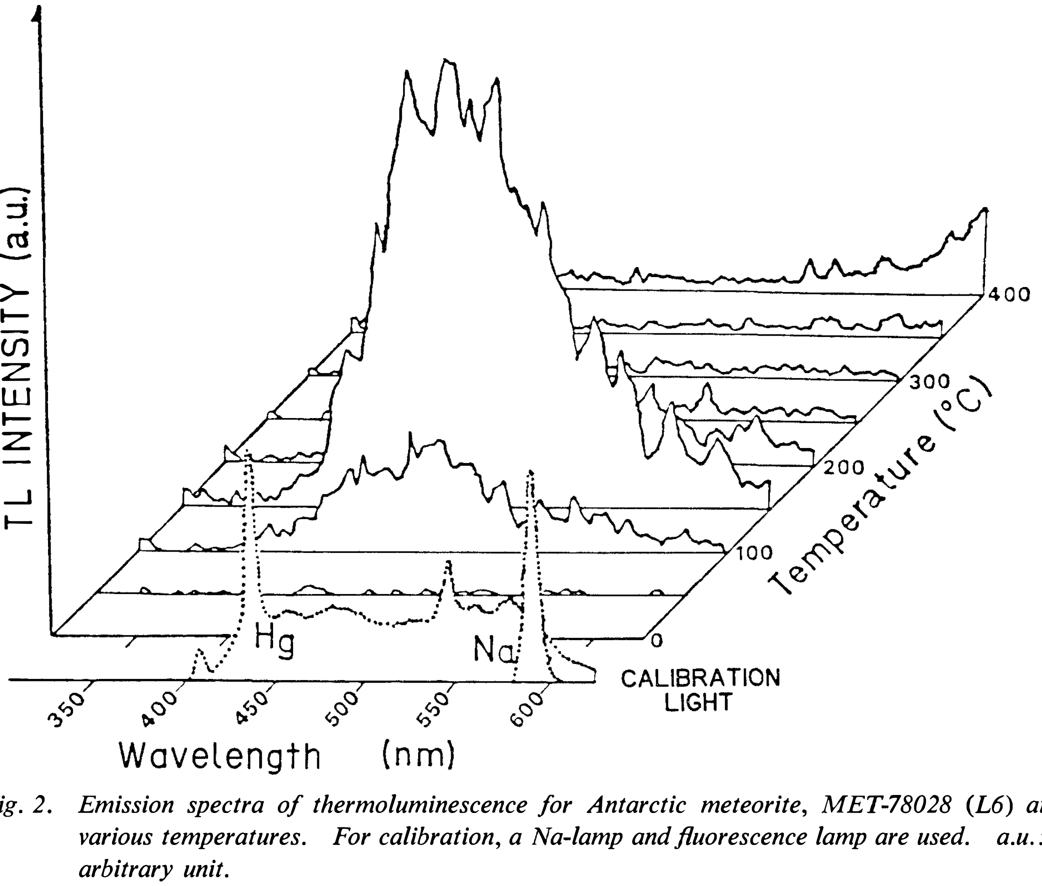

Fig. 2. Emission spectra of thermoluminescence for Antarctic meteorite, MET-78028 (L6) at various temperatures. For calibration, a Na-lamp and fluorescence lamp are used. a.u.: arbitrary unit.

4. Spatial Distribution of Natural TL near Fusion Crust

The sample, MET-78028(L6) was also gently cut in pairs perpendicular to fusion crust by a 0.01 inches wire-saw. One slice of a pair was artificially exposed to γ-rays from ^{60}Co and was given a dose of 1 kR in addition to natural dose. The pair of slices and an interior piece of the meteorite were set on a heater. The sample setting is shown in Fig. 3a.

To estimate the terrestrial age of this meteorite using a surface portion, TL spatial

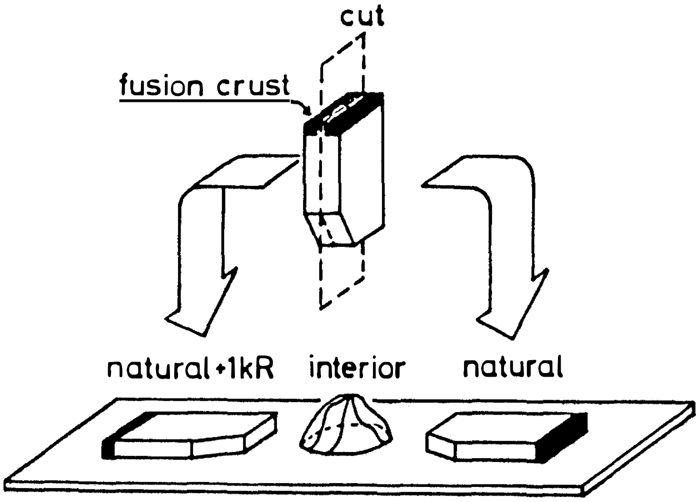

Fig. 3a. Cutting and setting on a heater.

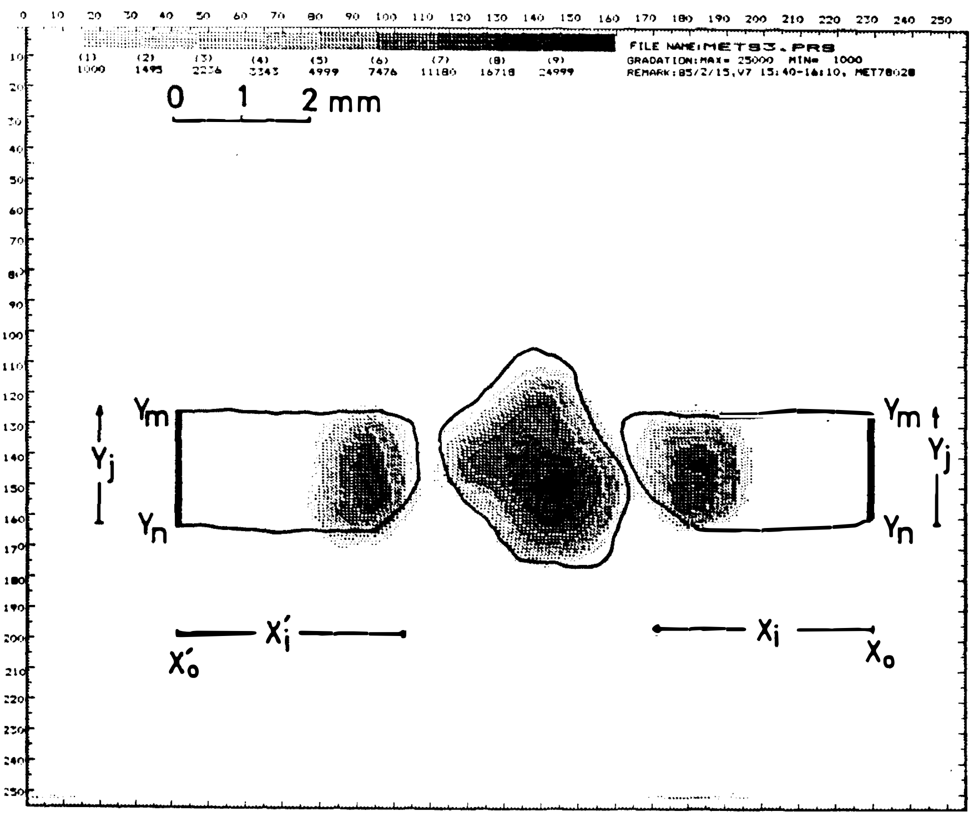

Fig. 3b. Spatial distribution of natural thermoluminescence for slices in pair and for interior one.

distributions of these samples were measured with the band pass filter, Corning 4-96 (blue-green) (this filter is suitable for MET-78028; refer to Section 3) and recorded onto a video cassette tape for about 160 s (about 4800 frames). TL images accumulated by the video image processor were printed. The position of high TL intensity is put by deep black points in Figs. 3b, 3c, 4b and 5b. The TL intensity is represented logarithmically in Figs. 3b and 3c.

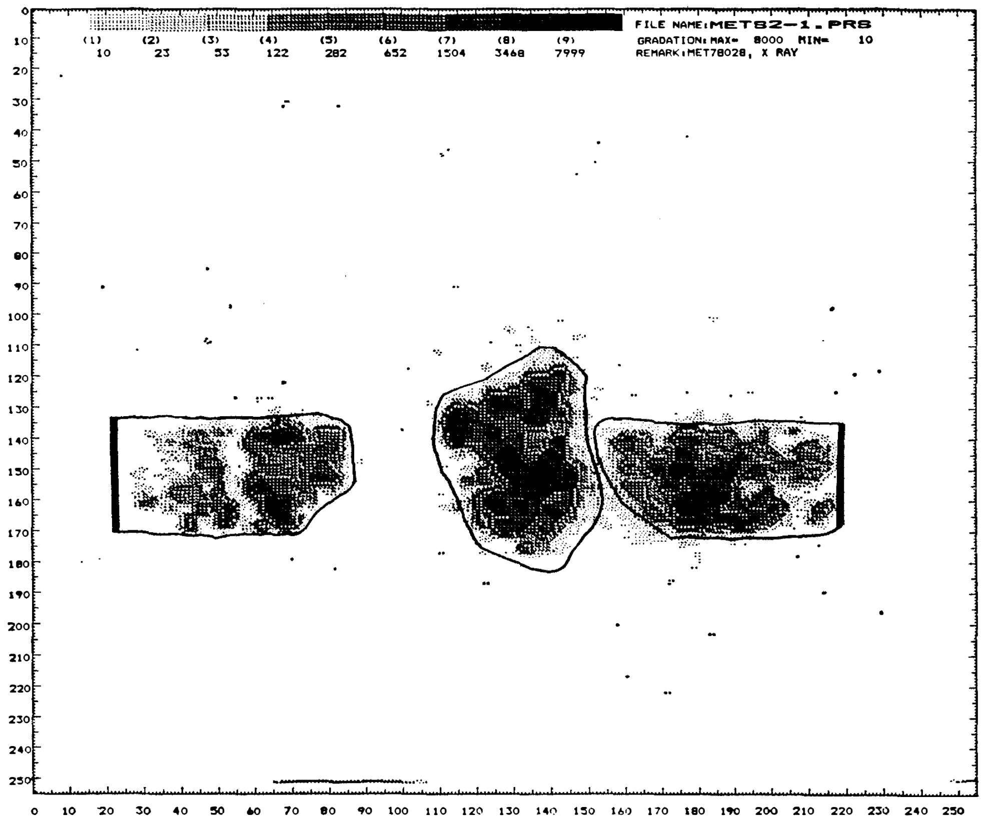

Fig. 3c. Spatial distribution of thermoluminescence sensitivity. The meteorite was irradiated with about 10^5 R X-ray.

Figs. 3(a–c). Spatial distribution of thermoluminescence for Antarctic meteorite, MET-78028 (L6) near fusion crust. The thermoluminescence intensity is represented logarithmically.

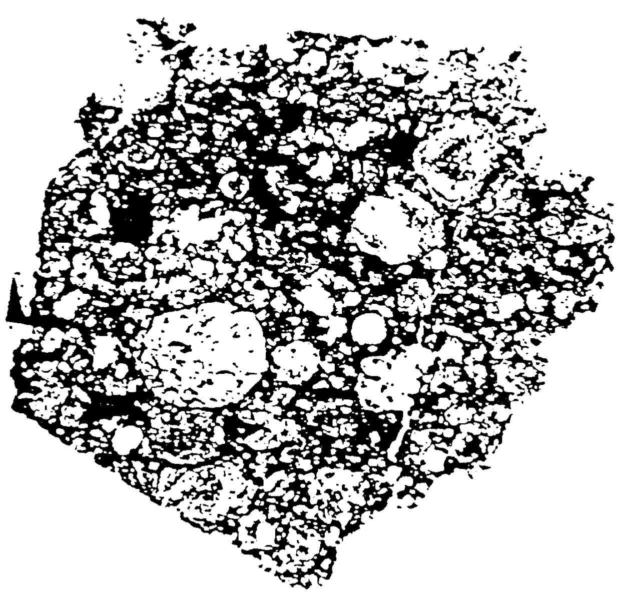

Fig. 4a. Photograph through a polarizing microscope.

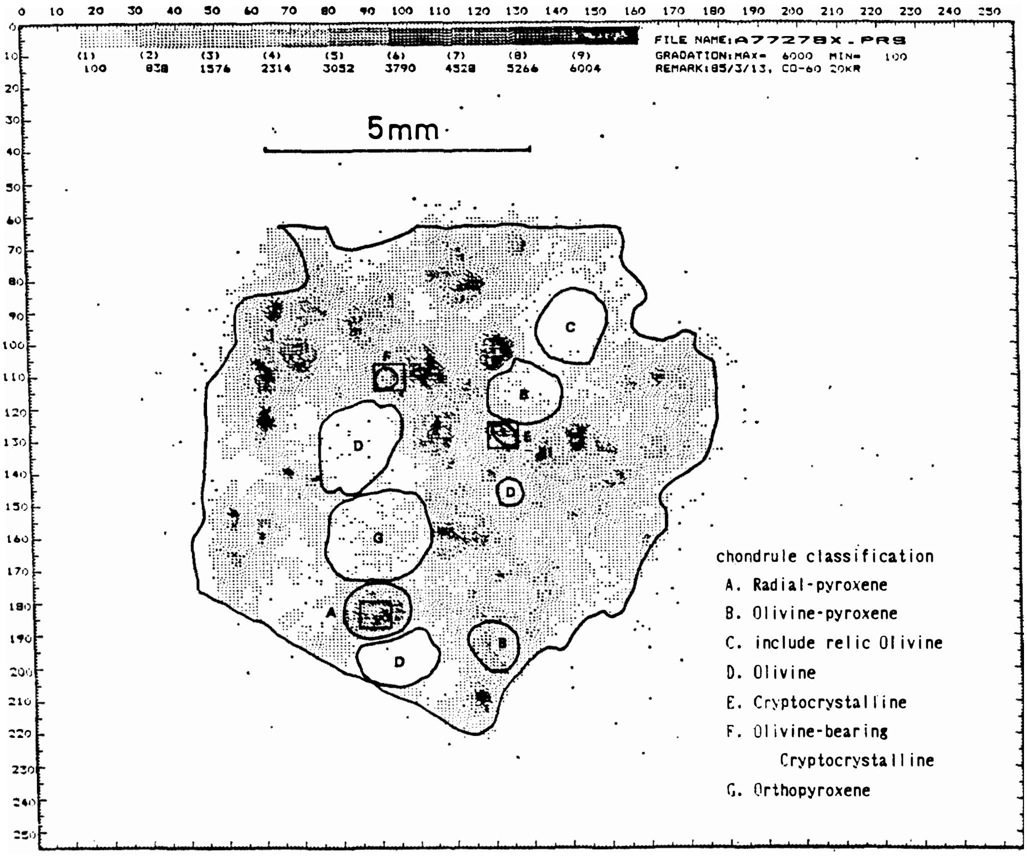

Fig. 4b. Spatial distribution of thermoluminescence.

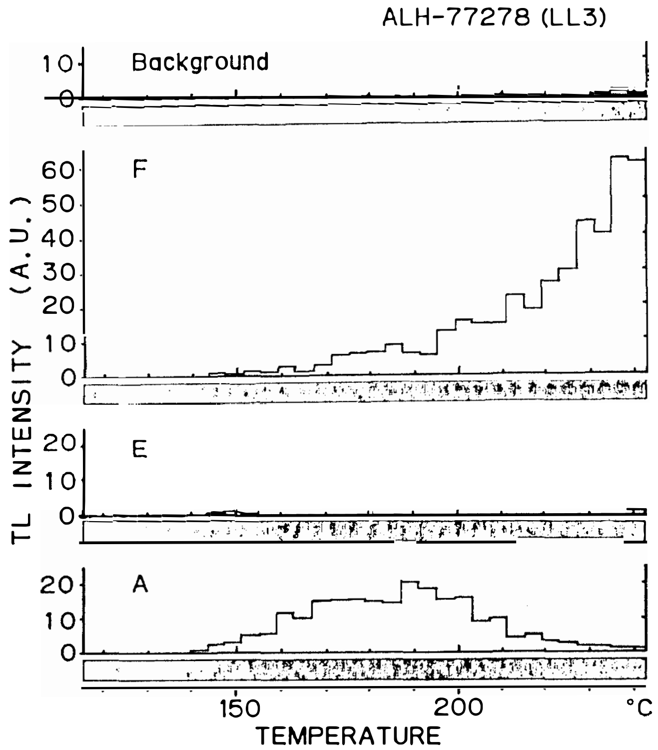

Fig. 4c. Glow curve of chondrules.

Figs. 4(a–c). Spatial distribution of thermoluminescence sensitivity for Antarctic meteorite, ALH-77278 (LL3). The meteorite was irradiated with 20 kR γ-rays after annealing.

Fig. 5a. Photograph through a polarizing microscope.

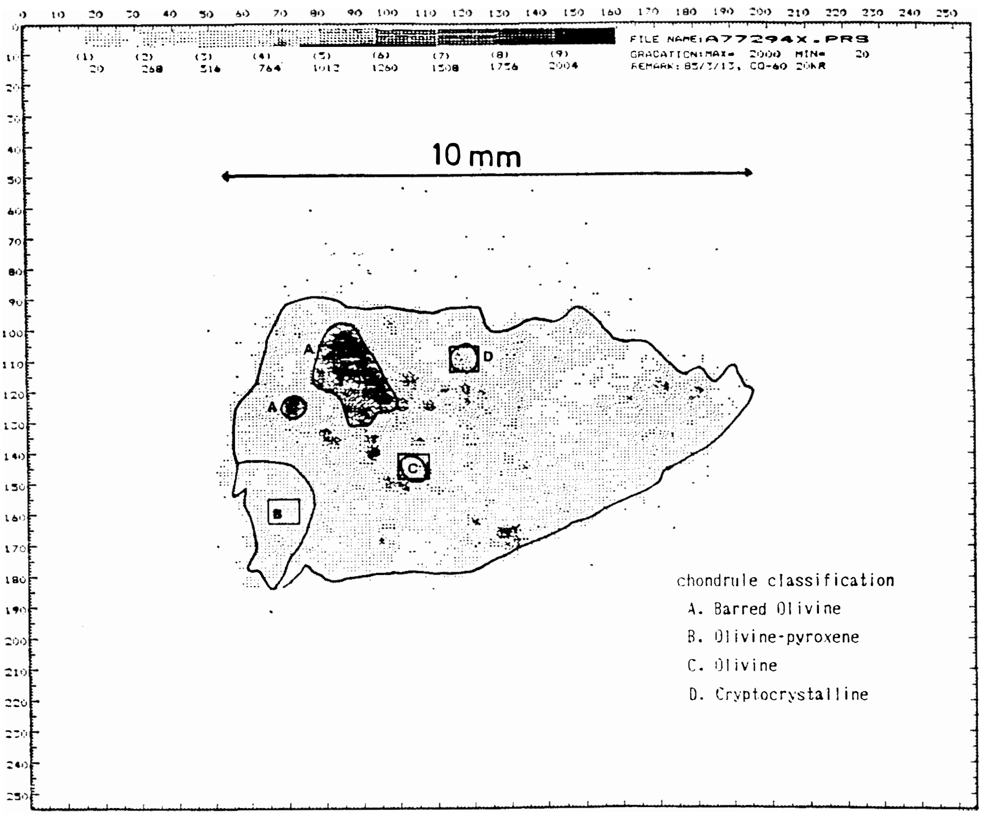

Fig. 5b. Spatial distribution of thermoluminescence.

Figure 3b is a spatial distribution of natural TL near fusion crust. The TL yield of both slices was not detectable at near fusion crust. This fact is due to frictional heating near the surface of meteorite during atmospheric entry. The TL yield was obtained from frame memory corresponding to each pixcell of frame. A TL intensity of a pixcell (x_i, y_j) is represented with I_{ij}. As shown in Fig. 3b, the y-axis is parallel to fusion crust and the x-axis is perpendicular to fusion crust. Each TL yield was read out with respect to a distance from fusion crust. That is;
for natural dose (the right side slice of Fig. 3b)

$$I_i = \sum_{j=n}^{m} I_{ij}(x_i, y_j) ,$$

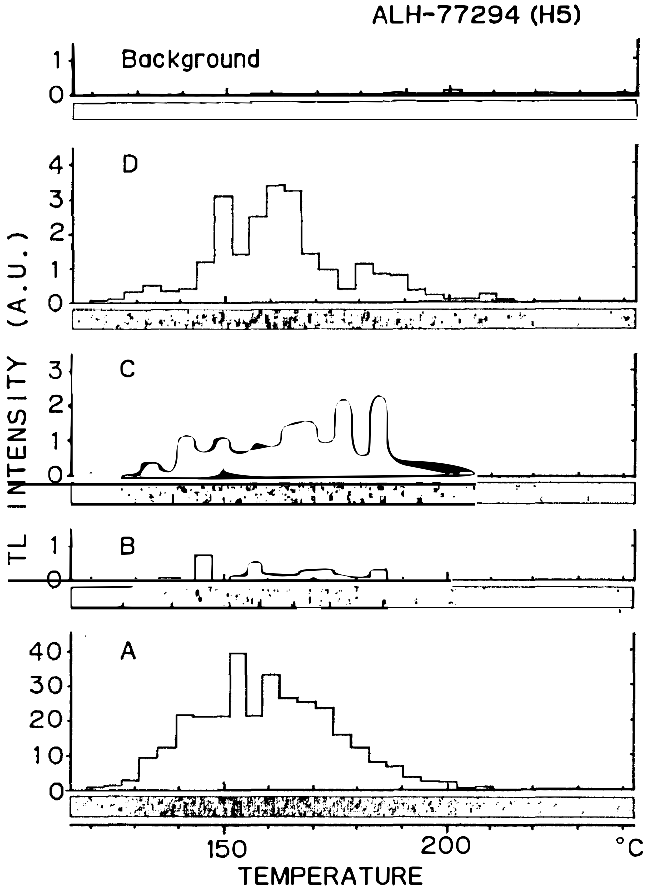

Fig. 5c. Glow curve of chondrules.

Figs. 5(a–c). Spatial distribution of thermoluminescence sensitivity for Antarctic meteorite, ALH-77294 (H5). The meteorite was irradiated with 20 kR γ-rays after annealing.

for (natural+1 kR) dose (the left side slice of Fig. 3b)

$$I'_i=\sum_{j=n}^{m} I'_{ij}(x'_i, y_j)\,.$$

In this measurement,

$$I_i>I'_i \quad \text{near fusion crust}\,.$$

This is contradictory to a prediction that TL would increase by the additional artificial dose.

So we further studied the spatial distribution of TL sensitivity for each sample. After readout of natrual TL, samples corresponding to Fig. 3a were exposed to X-ray (about 10^5 R) and were heated. The spatial distribution of TL sensitivity for these samples is shown in Fig. 3c. Although the pieces have been cut from a sample by the thin wire-saw (0.01 inches in width), two TL patterns shown in Fig. 3c have no similarity to each other. On the other hand, TL sensitivity near fusion crust is less than that of other portions.

5. TL Glow Curves of Chondrules

We have measured the spatial distribution of TL sensitivity of two meteorites, ALH-77278(LL3) and ALH-77294(H5). These samples were polished to thin sections to identify chondrules. Figures 4a and 5a show photographs of these thin sections through a polarizing microscope, in which chondrule types are represented. After annealing they were irradiated with ^{60}Co γ-rays (20 kR) and were heated. TL spatial distribution of TL sensitivity of each portion is shown in Figs. 4b and 5b. Some chondrules have high TL sensitivity and other chondrules have low TL sensitivity or no sensitivity. Furthermore, time variations of TL image at several chondrules were read out in 16×16 pixcels, whose positions are shown in Figs. 4b and 5b by squares. The variations of TL image are shown in Figs. 4c and 5c. Glow curves shown in Figs. 4c and 5c are obtained by summing up TL intensities of 16×16 pixcels. In ALH-77278(LL3) a olivine-bearing cryptocrystalline chondrule has a different glow curve from other chondrules. In ALH-77294(H5) barred olivine chondrules have high TL sensitivity. The differences in glow curves would be due to the composition of each chondrule.

6. Conclusions

As shown in Fig. 2, the ordinary chondrite has a wide TL emission spectrum with a maximum at about 450 nm. This spectrum shows that of feldspar.

In natural TL measurement near fusion crust, we could easily measure "annealing effect" by frictional heating during atmospheric entry. But in the present case (MET-78028), it was difficult to estimate a terrestrial age using the meteorite's surface portion, because facing sliced samples had not the same TL pattern with each other and TL sensitivity near fusion crust was lower than other portions.

As shown in Figs. 4b and 5b the TL spatial sensitivity of meteorites is not uniform since meteorites are inhomogeneous materials. Furthermore, each glow curve (time-varying TL intensity) of chondrules is different. In this system TL glow curve can be measured under the same condition in one measurement. So, this system is a powerful tool for investigating TL properties of chondrules.

Acknowledgments

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