NATURAL AND INDUCED THERMOLUMINESCENCE DATA FOR TWENTY-FIVE 10-15 µm PARTICLES FROM THE LL3.0 ORDINARY CHONDRITE SEMARKONA: IMPLICATIONS FOR THE NATURE AND HISTORY OF PRIMITIVE SOLAR SYSTEM MATERIAL. J. P. Craig[1], (jpc05@uark.edu) and D. W. G. Sears[1,2]. [1]Arkansas Center for Space and Planetary Sciences, [2]Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR, 72701, USA.

Introduction: To develop our techniques for thermoluminescence (TL) analysis of small particles, and begin to understand the fine-scale properties of primitive solar system material, we have measured the TL properties of twenty-five 10-15 µm particles from Semarkona. Semarkona is the Type 3 ordinary chondrite which has been the least affected by parent body processes (e.g. metamorphism) and as such retains a unique memory of the materials and conditions present in the early solar system [1]. In a companion abstract we discuss the potential for this type of study for IDPs and cometary dust particles such as those collected from Comet Wild 2 by the Stardust mission [2]. All of these types of primitive material contain information on a fine scale that cannot be obtained on coarser scales even when material is available. Examples of previous fine scale studies of Semarkona are seen in refs [3-5].

Methods: Separate fragments of the meteorite were gently crushed with mortar and pestle and the resulting fine fraction was dispersed on a watch glass. Fine grains, averaging 10-15 µm in size, were handpicked from random locations on the watch glass, photographed under a digital microscope and placed in a dimple in the center of a 5mm Cu pan. The TL properties were then measured with a modified Daybreak Nuclear and Medical Inc. TL apparatus. After measurement of the natural TL (NTL) or "as received" TL, the sample was irradiated with a 200 µCi ^{90}Sr beta source for 3, 5 and 10 minutes and the induced TL (ITL) measured. A plot of TL emitted as a function of laboratory heating temperature known as the "glow curve" was recorded. In order to establish the stability of the apparatus and check for background noise black body curves were produced at the beginning and end of each day. A black body correction was made but usually only affected the highest glow curve temperatures.

Results: With our current methods we are able to reproducibly and reliably obtain data for every particle measured with a signal to noise ratio of better than 10. For reasons explained in the companion abstract [2] we measured the NTL and ITL intensity at glow curve temperatures of 250 and 400 °C which provided four measurements for each fragment. It was seen that the varying irradiation times did not significantly affect the strength of the ITL signal, presumably we are saturating the TL of these tiny particles, so we averaged the data. The count rates determined were not uniform but in general covered a factor of two. Two particles (numbers 11, 12) were brighter under all conditions reflecting sample heterogeneity rather than differences in mineralogy or history.

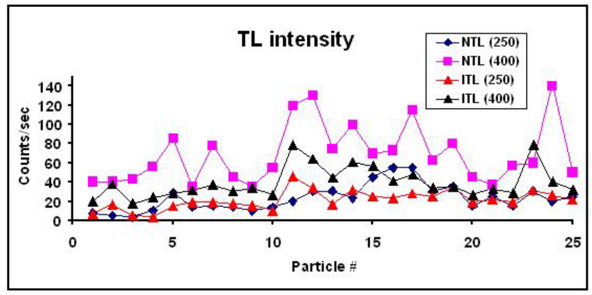

Fig. 1. *Natural and induced TL intensities for twenty-five 10-15 µm particles of the Semarkona LL3.0 chondrite at glow curve temperatures of 250 and 400 °C.*

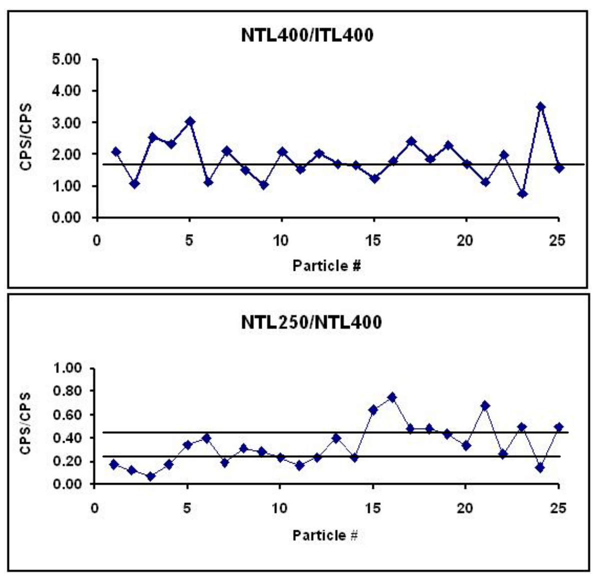

Fig. 2. *(a, upper plot) The ratio of the natural high temperature TL with the induced high temperature TL is uniform across the grains, implying a common radiation history. (b, lower plot) The ratio of the low temperature natural TL to the high temperature natural TL is a measure of the thermal history of the particles. The range of values seen suggests that these grains have experienced different thermal histories. The horizontal lines indicate preferred values.*

Discussion: There are three noteworthy observations we can make. First, we have obtained useful data for all of the 10-15 µm particles. We will not discuss this further other than to mention that our technique can now be reliably applied to IDPs and Stardust particles. Second, the induced TL properties are remarkably uniform for a meteorite known for its spectacular heterogeneity. In fact, the glow curves obtained for these small particles are very similar in shape to those obtained for homogenized bulk samples [6]. Third, despite these grains coming from such a close proximity to each other in the meteorite the natural TL shows significant differences.

The Semarkona meteorite is identified as type 3.0 partly because of the extremely low TL sensitivity (10^{-5} times that of common equilibrated ordinary chondrites) and the high level of mineral heterogeneity. It is not uncommon for macroscopic chips of these meteorites to vary by a factor of two in TL sensitivity. Cathodoluminescence images of Semarkona [10] show that while most of the meteorite has little or weak luminescence, about 5% of the chondrules have very bright luminescence. Apparently, in our 10-15 µm particles, we have avoided such unusual material. On the fine scale represented by our particles Semarkona has fairly uniform TL properties. Craig and Sears [6] argued that the luminescence of Semarkona matrix is dominated by forsterite. This conclusion is consistent with CL images that are dominated by very fine grains of forsterite with characteristic red CL [11].

Fig. 2 summarizes the natural TL data for these particles. The background to this form of presentation is explained in the companion abstract [2]. The NTL250/NTL400 ratio (which we will refer to as the “peak height ratio”) effectively measures the onset of the plateau and is largely a reflection of the thermal history of the sample. On the other hand, the NTL400/ITL400 ratio (the “plateau height”) effectively identifies the level of radiation experienced by the particles. To a reasonable approximation peak height ratio is used to extract information on terrestrial age and orbit for meteorites [7] while plateau height is routinely used in pottery dating and radiation dosimetry [8]. Our preliminary analysis of the data in Fig. 2 is that the plateau levels in these 10-15 µm particles are fairly uniform reflecting a common radiation history. The horizontal line in Fig. 2a indicates the average value. On the other hand, there appears to be two preferred values, Fig.2b, for the peak height ratio indicated by two horizontal lines which differ by about a factor of two.

Variations in the natural TL of these 10-15 µm particles from Semarkona are difficult to understand. The original fragment from which these particles were obtained was on the order of 0.5 grams which is too small for macroscale thermal gradients. Several authors have investigated natural TL profiles in meteorites and either found none or found factors of two over decimeters or more [e.g. 9]. The original fragment from which the present particles were taken was well clear of the fusion crust and were never heated above room temperature during storage and processing.

In our companion abstract we discussed four possible radiation and thermal histories for particles being emitted by a comet nucleus and we identified four categories of particles, A-D [2]. These could be identified using the data in Fig. 2. If this were the case we would suggest a different preaccretionary surface history for the high and low peak height ratio particles. However, this seems unlikely for an ordinary chondrite that was lithified soon after formation. An alternative explanation would be that there were thermal heterogeneities in the meteorite such as might be expected if an occasional hot chondrule were embedded in the cold dust and metal that was to become the meteorite. Another possibility would be hot spots created by minerals with different thermal properties following a thermal event like that associated with shock. In any event, these differences in peak height ratio caused by different thermal events would have to post date or survive the effect of the cosmic ray exposure that is usually assumed to be responsible for most of the natural TL signal in meteorites.

Conclusions: We have been able to reliably and reproducibly measure natural and induced TL properties of twenty-five 10-15 µm particles from the Semarkona LL3.0 ordinary chondrite. This size range is comparable to IDPs and Stardust particles. Glow curve shape and induced TL levels are uniform suggesting common mineralogy. The plateau levels of the TL (normalized high temperature natural TL) are also uniform, suggesting common radiation history for the particles, but the levels of low temperature natural TL show significant variation suggesting differences in thermal history. This implies highly localized thermal heteorogeneity in the meteorite, perhaps primary, perhaps shock related.

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