THE NATURE AND ORIGIN OF SEMARKONA FINE GRAINED MATRIX: AN INDUCED THERMOLUMINESCENCE STUDY. J. P. Craig[1] and D. W. G. Sears[1,2], [1]Arkansas Center for Space and Planetary Sciences and [2]Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701,USA. (jpc05@uark.edu).

Introduction: Following a previous study on fragments of separated opaque matrix from the unequilibrated ordinary chondrite Semarkona [1], we have now examined the thermoluminescence (TL) and chemical composition of micrometer fragments of matrix from the same meteorite. The unequilibrated ordinary chondrite Semarkona is the most primitive of ordinary chondrites, being low in TL sensitivity, high in mineral and phase heterogeneity, high in volatile elements and compounds having co-existing mineral phases that are far from equilibrium [2]. Our present objective is to measure the induced thermoluminescence and chemical composition of Semarkona matrix fragments in order to identify the component mineral phases responsible for the observed TL. Identification of these phases will provide a better understanding of primitive solar system material [3,4], and, eventually, provide a comparison for analysis of particles collected by the Stardust mission [5].

Samples and Experimental Procedure: From the earlier study of matrix fragments we selected particles previously designated as SM-4-1/1, SM-4-1/2 and SM-4-1/3 [1]. The ~300-500 micrometer sized samples were crushed using mortar and pestle and imaged under a petrographic microscope with video camera attachment. Relatively clean matrix was readily recognized by its fine-grained texture and dark appearance. Microscopic imaging of the crushed Semarkona matrix provided 8 samples ~50-100 micrometers in size which were isolated and re-designated SM-1 through SM-8. Each sample was drained of any natural TL by momentarily heating it to ~500°C. The samples were then individually exposed to a ^{90}Sr beta radiation source for three minutes followed immediately by measurement of the induced TL. The same procedure was repeated for 5 terrestrial forsterite samples obtained from Ethiopia designated ET-1 through ET-5 which are ~1 mg each. After completion of the TL measurement the Semarkona micrometer fragments were imaged at two magnifications using a Philips Model XL30 ESEM with EDX attachment under high vacuum to determine chemical composition.

Results: The fragments of matrix discussed here were obtained from three coherent pieces of matrix isolated from the meteorite. All show the expected structure of blocky coherent fragments with fractures and included grains. Fig. 1 shows the induced TL peak temperature and peak width for the present matrix samples compared with these data for larger (~500 μm) samples of Semarkona matrix (referred to as “bulk”), mg-size samples of type 3 ordinary chondrites, and the terrestrial forsterites. Induced TL peak temperature and peak width have been shown to be important parameters for characterizing the mineral phases – with particular regard to metamorphic history – in chondrites.

Half of the new Semarkona matrix fragments plot well outside the field occupied by the previous materials, while half plot in the gap between type 3.1-3.5 and 3.5-3.9 field or at the lower region of the 3.5-3.9 field. The terrestrial forsterites plot at the upper limit of the type 3.1-3.4 field, below the peak temperatures for the Semarkona matrix grains. As observed in previous work, the Semarkona bulk samples plot randomly over the figure.

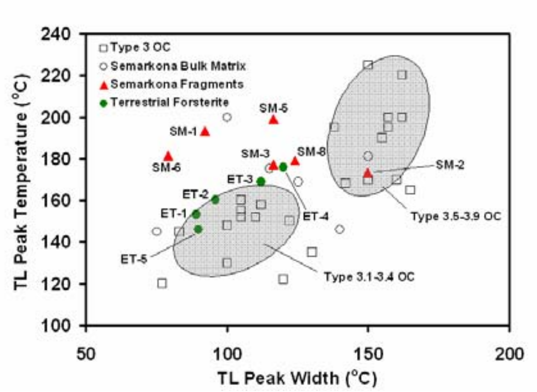


Fig. 1. *Induced TL properties of the present Semarkona fine-grained matrix compared with “bulk” Semarkona matrix samples, unequilibrated ordinary chondrites, and terrestrial forsterites (ET) [6]. The two ellipses refer to fields occupied by type 3.1-3.4 (lower) and type 3.5-3.9 (upper) ordinary chondrites, respectively.*

Compositionally, all reported Semarkona fragments contain abundances of most elements that are similar to Semarkona bulk matrix composition (Fig.2), although SM-1 shows elevated levels of Al and Ca with depletions in S relative to Semarkona. SM-2 on the other hand displays excess Ni and Mn in addition to the S depletion. SM-3 also shows the S depletion but is similar to Semarkona in other respects. SM-5 and 6 display elevated amounts of Al and Mg relative to Semarkona bulk matrix but like SM-3 they are otherwise similar in composition when compared.

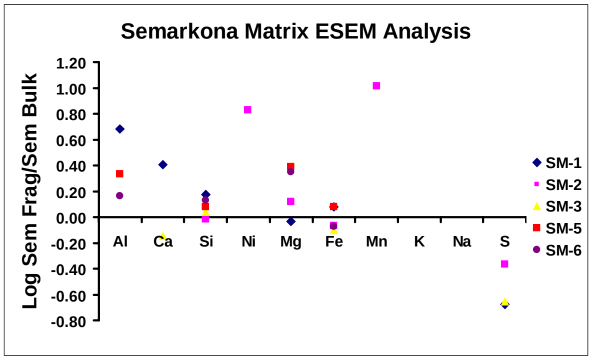
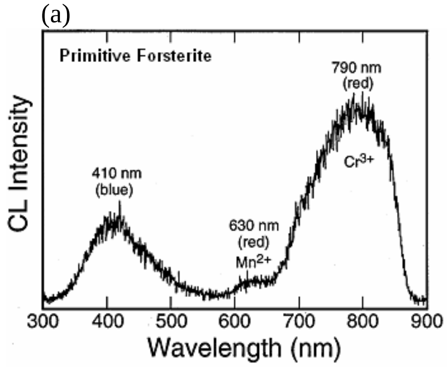


Fig. 2. *Elemental abundances of the five fragment particles extracted from the Semarkona meteorite, normalized to Semarkona bulk abundances. The Semarkona bulk matrix data are the average of six 10 μm beam EMPA analyses [7].*

(a)



(b)

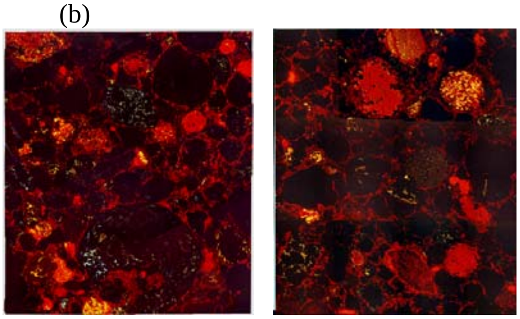


Fig. 3. *(a) Spectroscopic analysis of CL intensity of primitive forsterite [8]. (b) CL image of Semarkona fine grained matrix [9].*

Discussion: The luminescence properties of Semarkona have been examined thoroughly by cathodoluminescence (CL) [9]. In chondrules and inclusions the luminescence is caused by feldspar (or more precisely incipient crystallization in chondrule glass) and forsterite grains. In the matrix, the luminescence is caused by a uniform and dense distribution of micrometer-sized grains. Based on CL spectra, we have always assumed that these grains were forsterite and electron microprobe analysis of the similar coarse grains in chondrules confirms this. Thus the hummocky shape of the induced TL glow curves for Semarkona, including most bulk matrix samples, are consistent with the luminescence being caused by a mixture of various feldspars, forsterite, and perhaps minerals in refractory inclusions. Iron diffuses into the forsterite very quickly with traces of metamorphism quenching its luminescence and glass crystallizes to highly luminescent feldspar showing a rapid increase in the levels of induced TL. Since we have always assumed that the source of matrix luminescence was forsterite the present data were easily explained since they plotted apart from the feldspathic ordinary chondrites.

However, the different properties of the present matrix samples and our terrestrial forsterites needs to be explained and the explanation may have important implications for our understanding of the nature and origin of Semarkona matrix. There might also be implications for understanding the forsterites in Stardust particles and the forsterite Koike et al. suspect to be present in the extended red emission (ERE) from the Red Rectangle nebula [10, 11]. In the absence of data for more terrestrial forsterites of different origins we can only speculate, but it seem highly likely that forsterite produced by crystallization in an igneous environment, such as during chondrule origin, will have very different defect structure and therefore luminescence properties than forsterite produced, say, by vapor deposition.

Conclusions: It is clear that forsterite is an important component of many primitive inner and outer solar system materials and probably more distant astronomical objects. The difference in induced TL properties of the Semarkona fine-grained matrix and the terrestrial forsterites suggests that a detailed study of terrestrial forsterites, Semarkona chondrule forsterites and Stardust forsterites will provide important insights into the origins of these primitive astronomical materials.

References:

[1] Craig *et al.* (2007) *LPI XXXVIII #1095*. [2] Sears *et al.* (1995) *Meteoritics 30*, 169-181. [3] Gucsik *et al.* (2007) *LPI XXXVIII #1051*. [4] Huss *et al.* (1981) *GCA 45*, 33-51. [5] Brownlee *et al.* (2006) *LPI XXXVII #2286*. [6] Guimon *et al.* (1984) *Nature 311*, 363-365. [7] Sears *et al.* (1999) *MAPS 34*, 497-525. [8] Benstock *et al.* (1997) *Amer. Mineralogist 82*, 310-315. [9] Akridge *et al.* (2004) *JGR 109*, E07S03. [10] Zolensky *et al.* (2006) *Science 314*, 1735-1739. [11] Koike *et al.* (2002) *Meteoritics and Planetary Science 37*, 1591-1598.