DIFFERENCES IN THE METAMORPHIC HISTORY OF HIGH PETROLOGIC TYPE EH AND EL CHONDRITES AND THE LUMINESCENCE PROPERTIES OF ENSTATITE. D.M. Schneider, Y. Zhang, D.W.G. Sears, and P.H. Benoit. Cosmochemistry Group, University of Arkansas, Fayetteville, AR 72701 USA. Internet: cosmo@uafsysb.uark.edu.

The enstatite chondrites are a rare class of meteorites whose high state of reduction makes them especially important. Like the more common ordinary and carbonaceous chondrites, enstatite chondrites exhibit a range of petrographic and mineralogic features which indicate that they have experienced a wide range in metamorphic alteration while on their parent bodies. We have attempted to further constrain the metamorphic history of enstatite chondrites, particularly differences between metamorphosed EH and EL chondrites, using their cathodoluminescence (CL) properties. We find that we can alter the CL properties of EL6 chondrites to more closely approximate those of EH6 chondrites by annealing an EL6 chondrite in an inert atmosphere for fairly short times at high temperatures. These changes in CL properties appear to be the result of changes in the degree of crystallographic order of the enstatite between the two meteorite classes, and confirm earlier proposals that EL chondrites of high petrologic type contain enstatite in the ordered form and therefore experienced a longer period of metamorphism at low temperatures than did EH chondrites.

In our previous studies of the luminescence properties of enstatite chondrites [1,2], we noted complex differences in the CL properties of enstatite meteorites of various petrologic types and compositional classes. Of particular interest, we noted that while the enstatite in EH6 chondrites exhibited a fairly homogeneous blue CL, EL6 chondrites exhibited an intense magenta CL. Changes in the luminescence properties of enstatite as a function of metamorphism can be understood in terms of changes in minor element contents [3], since the concentration of elements such as chromium, manganese, and titanium, which play important roles as luminescence centers and inhibitors [4], decrease during metamorphism. However, differences between highly metamorphosed EH and EL chondrites are more difficult to explain and are not observed among the various classes of ordinary chondrites. We have suggested that these properties reflect significant differences in the degree of ordering of the enstatite in EH and EL chondrites caused by differences in the metamorphic history of these two classes [2]. If these ideas are correct, then laboratory annealing experiments designed to disorder ordered enstatite should have major effects in the CL and crystallographic properties of an EL6 chondrite. Similar experiments on feldspar have enabled successful interpretations the luminescence properties of ordinary chondrites [5] and achondrites [6].

Methods. A 4 g sample of the EL6 chondrite ALH 81021 was crushed to a homogeneous powder of approximately 100 mesh grain size, metal was removed using a magnet, and 100 mg splits were placed in silica glass tubes. The tubes were then evacuated three times and purged with nitrogen, heat sealed, and placed in a furnace at ~ 1070 °C for 10, 50, 100, 200 and 1000 hours. The annealed powders had the same macroscopic appearance as unannealed powder, but in a few cases poor sealing or tube failure caused the powders to appear much darker than the original. We examined the samples by a variety of analytical techniques, but here concentrate on the CL and X-ray powder diffraction results.

Results and Discussion. *Cathodoluminescence.* The CL of unannealed powder of ALH 81021 is a homogenous magenta of moderate intensity, similar to that of other EL6 chondrites [2]. As observed previously, the only important CL phosphor in E chondrites is enstatite. The CL of the annealed samples showed distinct differences from that of the unannealed powder. After only 10 hours of annealing, a small number of the enstatite grains had acquired a yellow-green CL, in place of their previous magenta CL, and this was especially true of the smaller grains. As the duration of annealing increased, the proportion of grains exhibiting yellow-green CL increased, until, after 1000 hours, virtually all grains exhibited the yellow-green CL. The overall intensity of the CL also appeared to decrease slightly. These changes in CL properties are clearly not a result of oxidation because the CL of samples from damaged tubes was an intense red CL; very different from either the magenta of the unannealed powder or the yellow-green of annealed powder.

As in our earlier work, we quantified the data by measuring the transmittance spectra of the photographic negatives [2]. Obviously this procedure is not as exact as direct spectroscopy of the CL, but is quick and has the advantage of easily integrating time and area. We also determined the proportions of yellow-green and magenta grains by noting the grains which fell on the intersections of a transparent grid overlaid on the prints. Both techniques enabled us to quantify the process whereby grains with magenta

CL transformed to grains with yellow-green CL and gave very similar results (Fig. 1). Preliminary data reduction suggests that the transformation process most closely follows first-order kinetics.

X-ray Powder Diffraction. Ideally one would like single-crystal X-ray diffraction data for these samples, but the small grain size of these meteorites precluded this. We therefore used a bulk powder method described by Pollack and Ruble [7], which uses the ratio of the 420/221° doublet to the 610 ° X-ray peak, to determine the relative abundance of order to disordered feldspar. Despite a number of difficulties, such as the presence of peaks due to phases other than enstatite, the ratio of the doublet to the 610 ° peak generally increased in the manner expected after disordering during the annealing.

Conclusions. Our data support the idea that enstatite in high petrologic type EH and EL chondrites is in different structural forms, with enstatite in EH chondrites being predominantly disordered while that in EL chondrites is predominantly ordered. As discussed elsewhere [1], this implies an extended period of low-temperature metamorphism for the metamorphosed EL chondrites which was not shared by the EH chondrites.

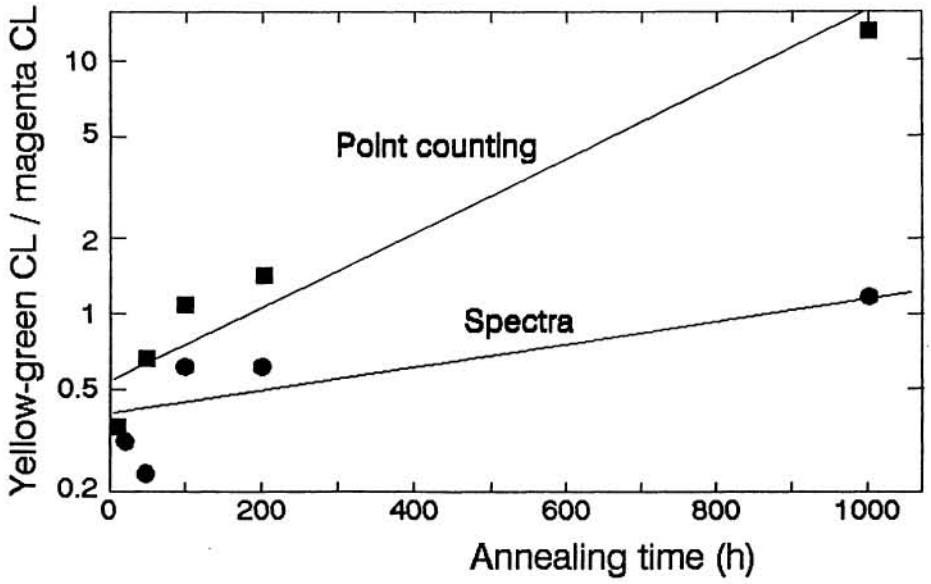

Fig. 1. Changes to the cathodoluminescence of the EL6 chondrite ALH 81021 caused by annealing at 1070 °C as a function of annealing time. The curves give the ratio of the intensity of yellow-green CL to the intensity of magenta CL, as determined from visible transmittance spectra of the photographic negatives, and the ratio of the number of grains displaying yellow-green CL to the number showing magenta CL, as determined by point counting.

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