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THE OCCURRENCE OF BLUE LUMINESCING ENSTATITE IN E3 AND E4 CHONDRITES. John M. DeHart+ and Gary E. Lofgren*. +1914 Amherst Ave., Casper, WY 82601. *SN-4, NASA-JSC, Houston, TX 77058.

Introduction. Two compositional types of enstatite that emit Cathodoluminescence (CL) are known to exist in E3 and E4 chondrites. The first type consists of the most common enstatites that are relatively FeO-poor (Approx. En_{98}) and emit a red CL. Their CL is apparently activated by the presence of MnO and Cr_2O_3 in concentrations of 0.2 to 0.6 weight percent. The second type of enstatite is nearly FeO-free (>En_{99}), contains no MnO or Cr_2O_3 and emits a blue CL. The origin of these two types of enstatite and their accompanying chemical and CL differences has long been a subject of discussion. Leitch and Smith [1] first observed the two types and felt the compositional differences were too great to have formed under the same conditions. They postulated the two types of enstatite formed on separate parent bodies and were mixed when these bodies collided. McKinley et al. [2] observed a continuous range of compositions between blue luminescing and red luminescing enstatites and concluded the two types of enstatite formed by similar mechanisms (i.e. growth from a preexisting melt). Recently, Lofgren et al. [3,4] presented evidence that blue luminescing pyroxenes were relicts that did not completely melt during the heating event which melted other precursor grains, and are distinct from the red CL pyroxene in the chondrules in E chondrites. In order to further clarify the nature and origin of the pyroxene that emits blue CL, the sections listed in [5] were examined for the occurrence of blue luminescing enstatite.

Observations. In general, the blue luminescing enstatite we observed can be divided into three groups. There is a banded variety with bands of bright blue and pale pink to violet CL that appear to be associated with polysynthetic twinning. Occasionally, the pink to violet bands are replaced by duller blue luminescing bands. A second group of enstatites has CL that is uniformly blue over the entire area of the grain. The third type is similar to the enstatites that emit uniform blue CL, but has irregular, duller blue luminescing patches occurring throughout the grain.

Banded, blue luminescing enstatite occurs exclusively in MAC88136 and LEW87223. It is found as euhedral to subhedral grains in chondrules, clasts, refractory inclusions and grain fragments in the interchondrule matrix of MAC88136. It is likely that this type of blue luminescing pyroxene is unique to EL3 chondrites. This is also the only type of blue luminescing enstatite that has been produced in activator -depleted, dynamic crystallization experiments [4].

Unbanded, uniformly blue luminescing enstatite occurs most often as whiskers or grains embedded in kamacite. The proportion of enstatite to kamacite varies widely, from isolated 3 to 5 um wide whiskers of enstatite that are embedded in isolated grains of metal, to chondrules 200 to 300 um in diameter composed of grains of blue luminescing enstatite with interstitial metal and/or sulfide. While the latter cases are found only in the EL chondrites studied, the others are found in all E3 and E4 chondrites. It is unusually abundant in PCA82518, whose interchondrule matrix is dominated by metal/sulfide aggregates with grains of uniformly blue luminescing enstatite embedded in kamacite.

Uniformly blue luminescing enstatite also has three other notable occurrences. First, it is nearly the exclusive phase found in the interchondrule matrix of LEW87223. Second, it can be found as 5 to 10 um wide overgrowths after red luminescing pyroxene in chondrules and clasts found in both EH and EL chondrites. Finally it can be found in association with other refractory minerals in objects identified as refractory chondrules and aggregates.

The third type of enstatite, the unbanded, uniformly blue luminescing enstatite with irregular, duller blue luminescing patches appear to be mostly relict grains. It is most often found in chondrules and as isolated grain fragments in EH chondrites. This enstatite occurs as isolated blue luminescing relicts surrounded by red luminescing enstatites which appear to have grown from the surface of the blue luminescing grain. These mottled blue luminescing enstatites often contain small inclusions of Mn-rich sulfides. Also, aggregates of this type of blue luminescing enstatite, metal and a dull blue luminescing quartz or nearly pure SiO_2 glass can be found surrounded by red luminescing enstatite that appears to have grown from their surfaces.

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Discussion. These three types of blue luminescing pyroxenes clearly have different histories. The variety with CL banding apparently formed from igneous melts depleted in activator cations and appear not to have experienced other alteration effects since their formation. In contrast, the history of the uniformly blue luminescing enstatite appears to be more complex. CL banding in blue luminescing enstatite grown in dynamic crystallization experiments can be eliminated by reheating [4]. This presumably can explain the uniform blue CL of the unbanded blue luminescing enstatite, but cannot explain the duller blue patches found in the mottled blue luminescing relict grains in E3 and E4 chondrites. In some instances (i.e. the blue luminescing pyroxenes included in kamacite), it may also indicate the enstatite formed by mechanisms other than growth from an igneous melt, such as gas-solid condensation. Both of these phases can condense from a gas of solar composition in the same range of temperatures and pressures [6]. It is possible the enstatite condensed first, then acted as nucleation sites on which the kamacite would nucleate and grow when conditions of the cooling gas became oversaturated in this phase.

Conclusions. No simple explanation can account for the occurrence of all blue luminescing enstatite in E-chondrites. While it appears blue luminescing enstatite with CL banding has the simplest history (i.e. formation from a preexisting melt), the unbanded blue luminescing enstatite appears to have a more complex history that involves either reheating or formation by mechanisms other than growth from a preexisting melt.

References: [1] Leitch and Smith (1982) *GCA* **46**, 2083-2097. [2] McKinley et al. (1984) *Proc. 14th Lunar Planet. Sci. Conf., Part 2, J. Geophys. Res.* ***89***, *Supplement*, B567-572. [3] Lofgren G.E. and DeHart J.M.. (1992) *Lunar and Planetary Science, XXIII*, pp. 801-802. [4] Lofgren G.E. et al. (1992) *Lunar and Planetary Science, XXIII*, pp. 799-800. [5] Lofgren G.E. and DeHart J.M..(1993) *Lunar and Planetary Science, XXIV*, pp. 893-894. [6] Grossman, L. (1972) *GCA*, **36**, pp. 597-619.

Table 1. Representative electron microprobe analyses of the different varieties of blue luminescing enstatite in E3 and E4 chondrites. Values are in weight percent. B = banded, UB = unbanded, En = enstatite, refract = refractory, incl = inclusion, kam = kamacite

Sample Description	SiO_2	Al_2O_3	FeO	MgO	CaO	Total	No. Cations per 6 oxygens
MAC88136:							
B chondrule En	59.02	0.17	0.29	39.76	0.35	99.59	4.009
LEW87223:							
UB En in matrix clast	59.33	1.52	0.40	40.22	0.06	101.53	4.012
B En in refract incl	58.98	1.32	0.10	39.40	0.26	100.06	4.002
ALH84170:							
UB En after red En	59.93	0.12	0.16	39.91	0.05	100.17	3.999
UB relict En	59.75	0.12	0.49	39.36	0.05	99.77	3.997
UB En in incl in kam	60.42	0.10	0.46	39.91	0.07	100.96	3.997
PCA82518:							
UB En after red En	59.12	0.12	0.40	40.33	0.05	100.02	4.004
UB En in incl in kam	59.43	0.18	1.02	40.65	0.05	101.33	4.013