DYNAMIC CRYSTALLIZATION EXPERIMENTS AND CATHODOLUMINESCENCE STUDIES OF TYPE I CHONDRULE COMPOSITIONS.

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Introduction: Type I chondrules in the least altered type 3 ordinary chondrites have unique chemical (1) and Cathodoluminescence (CL) properties (2) that are probably related to their conditions of formation. The Fe-poor olivines and pyroxenes found in these chondrules most often emit red CL, although occasional grains that emit blue CL have also been noted (2, 3). The refractory mesostases that enclose these grains often emit yellow CL in chondrules found in meteorites of the lowest petrologic type (Semarkona and Bishunpur, types 3.0), but emit blue CL in meteorites of higher type. In order to see if this change in luminescence properties can be used as an indicator of low-level thermal metamorphism, we are conducting a two-stage series of experiments to explore how yellow luminescing mesostases can be formed and what conditions can alter the color of their CL emission. First, we are exploring the conditions of formation for this yellow phosphor with dynamic crystallization experiments using a composition (CH-6) similar to the average type I chondrule composition reported in (1). Second, experimentally produced charges that possess yellow luminescing glass are annealed under different conditions in order to determine what can cause the yellow phosphor to change it's CL properties.

Experimental: Standard gas-mixing and dynamic crystallization techniques were used for the dynamic crystallization experiments(4). The experimental liquidus temperature of the CH-6 composition was determined to be 1555°C. Grids of experiments have been conducted using cooling rates of 10°C/hr, 100°C/hr, and 1000°C/hr, and quench temperatures varied between 1350°C and 900°C. Three grids of experiments have been completed; the initial melt temperature for the first grid was set 15°C below the liquidus, the second at 5°C below the liquidus, and the third at 5°C above the liquidus. Two additional experiments were conducted in the first grid and were annealed at 1050°C and 1000°C for 1 and 19 hours, respectively, prior to quenching. All experiments were quenched in air.

Experiments with yellow luminescing glasses were reproduced and cut into 1 mm thick sections. These sections were placed in covered crucibles and annealed in a Thermolyne oven at 200°C, and 500°C for 150 hours. Another section was sealed in a gold capsule with 10 microliters of water and annealed at .5 bar for 150 hours at 200°C.

(Analytical Methods) The grains and glasses in each experiment have been analyzed by electron microprobe techniques. CL photographs of each experiment were made with a Nuclide Luminoscope attached Wild MPS45 Photomicroscope.

Results: Glass produced by quenching from the experimental liquidus was nonluminescent. The results of all three grids of experiments are similar in that glasses which emit bright yellow CL are present in only the experiments that were cooled at the slowest rates to the lowest temperatures or were annealed for a short period prior to quenching. Only those experiments that were cooled at 10°C/hr and 100°C/hr below 1000°C possess quench glass with a uniform yellow luminescence similar to that observed in type I chondrules. Both experiments that were annealed prior to quenching had glasses that emitted bright yellow CL, while the experiments that were cooled at the same rate but quenched immediately had only patches of glass with bright yellow CL around the outer perimeter of the charge. The quench glasses with yellow CL were always turbid while the nonluminescing glasses were clear and isotropic. In all cases the glasses emitting yellow CL are associated with aluminum-rich diopside occurring as microlites or as overgrowths on enstatite. In all but one case, the glasses producing the yellow luminescence are high in normative anorthite (>49%), which compares well with the composition of yellow luminescing mesostases in type I chondrules in Semarkona (see Fig. 1).

All the annealing experiments failed to alter the yellow CL emission of the experimental charges. Results of the 500°C experiment and the hydrothermally annealed experiment appeared to increase the amount of glass that produced yellow luminescence.

Interpretations: These experiments demonstrate that yellow luminescing glasses in type I

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chondrules can form by normal igneous fractionation processes that occur during crystallization. Fast cooling rates suppress the nucleation and growth of enstatite and diopside in the matrix from this composition, preventing further enrichment of the remaining melt in normative anorthite, which is strongly associated with the emission of yellow CL from these glasses. This strongly suggests that type I chondrules with yellow luminescing mesostases experienced slower cooling rates than previously proposed in (1). Rather than experiencing cooling rates from 100°C to 1000°C an hour, it is more likely these chondrules experienced cooling rates on the order of 10°C to 100°C an hour.

The results of the annealing experiments indicate the yellow luminescence is not derived from a metastable quench structure that can be destroyed by low levels of reheating in the presence or absence of water. Since the luminescence appears to originate from a larger area after annealing, the mineral responsible for the yellow luminescence appears to be a product of devitrification of the glasses in this composition. TEM investigations presently underway should identify the mineral responsible for the yellow luminescence and further clarify why the luminescence properties of type I chondrule mesostases appear to change with increasing petrologic subtype in the type 3 ordinary chondrites.

Conclusion: The phosphor emitting yellow CL in the mesostases of type I chondrules formed by the fractionation processes that occur during crystallization. This yellow luminescing phase is easily formed from melts that experienced slow cooling rates and/or isothermal annealing periods during their cooling history. Faster cooling rates appear to inhibit the phosphor's formation, indicating type I chondrules with yellow luminescing mesostases experienced cooling rates an order of magnitude slower (10°C to 100°C an hour) than previously proposed. The results of the annealing experiments indicate the phosphor producing the yellow luminescence is not a metastable product produced during quenching.

References. (1) Jones, R.H. and Scott, E.R.D. (1989) Proc. XIX LPSC, pp. 523-536. (2) DeHart, J.M., Lofgren, G.E. and D.W.G. Sears (1989), LPSC XX, pp. 228-229. (3) Steele, I.M. (1986) GCA, **50**, pp. 1379-1395. (4) Lofgren and Russell (1986) GCA, **50**, pp. 715-726.

Figure 1. Ternary plot of the major CIPW normative minerals calculated for the glasses in the experiments initially melted at 1540° C, and representative mesostases analyses of type I chondrules in Semarkona. Type I chondrule average is from (1) and filled symbols have glasses that emit yellow luminescence. Note that the remaining melt is less enriched in normative anorthite with faster cooling rates.