

THE COLOR OF METEORITIC HIBONITE

Stolper, E. and Thinger P.

spectrum of an orange experimentally produced hibonite is shown for comparison.

It is apparent that Ti is responsible in some way for the blue color. The experiments on BA-V demonstrate that, contrary to the suggestion in [4], V^{3+} is not required for this color. The V composition is pink + purple in color rather than blue under reducing conditions. The results on BA-VFC demonstrate that interactions involving Fe or Cr are also not required to produce the blue color and that it can be produced by Ti in the absence of other transition elements (unless contamination occurred in the course of starting material preparation or during the experiments). Significant amounts of Ti^{3+} cannot be invoked in view of the regularity in the Ti + Mg vs 2 Al correlation observed for meteoritic hibonites [4-6] and since the blue color persists to fO_2 levels higher than those normally required to stabilize substantial amounts of Ti^{3+} . The blue colors of BA-V and BA-VFC lack the greenish tinge of the BA and All-2 compositions but have the same absorptions at 400 and 700 nm. The transition from blue → white for the BA-V composition contrasts with the blue → orange transition of the BA and All-2 compositions; an interaction involving vanadium may be responsible for the orange color.

Discussion. The results of our experiments demonstrate that the colors of Allende hibonites (orange, colorless) reflect more oxidizing conditions than the blue color of hibonites from Murchison. Hibonites condensing from a gas of approximately solar composition at $1430^\circ C$ ($H_2/H_2O \sim 500-2000$, $fO_2 \sim 10^{-14.8}$ - $10^{-16.0}$ bars) would be blue. The orange and colorless hibonites from Allende would require extremely oxidizing nebular gases ($fO_2 > 10^{-7}$ bars, $H_2/H_2O < 0.07$ at $1430^\circ C$) if their colors were produced at the high temperatures at which these phases condensed. The HAL hibonite [6], which is colorless, has been previously suggested to have equilibrated with very oxidizing gas based on its Ce anomaly [8, 9]; this may reflect an unusual environment in the normally very reducing solar nebula [8], or condensation in a supernova [9]. Another possibility is that the colorless HAL hibonite formed by re-equilibration of initially blue hibonites under oxidizing conditions; the difficulties that we experienced with preserving equilibrium colors upon quenching our experiments suggests that such color changes would be difficult to avoid if an inclusion passed even briefly through oxidizing conditions at elevated temperatures. Immersion of the HAL hibonite in the melt from which its black rim quenched or other stages of secondary alteration inferred by [6] could easily have oxidized this hibonite. It is unlikely that the oxidation state implied by the orange hibonites in the CG-11 Type A CAI [5] reflects high temperature conditions in the region of the nebula where these hibonites formed, since the Ti^{3+}/Ti^{4+} ratios of fassaites in Allende, some of which are associated with orange hibonites in CG-11, suggest reducing conditions at high temperatures that are consistent with equilibration with gas of approximately solar composition [10]. There is, however, evidence for extensive re-equilibration and alteration of the CG-11 inclusion through interaction with an oxidizing non-solar gas at lower temperature than that at which the hibonite would have condensed [5, 11]. The orange color of hibonite in CG-11 would suggest, then, that although the presence of hibonite is a result of high temperature processes, the hibonites have been altered at lower temperatures. The preservation of the blue color in Murchison hibonites may be a reflection of the fact previously noted by others [e.g., 2, 3] that Murchison inclusions appear to have been removed from the nebular gas and prevented from further re-equilibration earlier and at a higher temperature than those found in Allende. It should be noted, however, that Murchison inclusions also appear to have been altered, perhaps under oxidizing planetary conditions [4]; the failure of the hibonites to change color may help to set limits on the temperatures accompanying this alteration.

References. [1] Fuchs et al (1973) *Smithson. Contrib. Earth Sci.* 10. [2] Macdougall (1979) *EPSL* 42, 1. [3] Bar-Matthews et al. (1982) *GCA* 46, 31. [4] Armstrong et al. (1982) *GCA* 46, 575. [5] Allen et al. (1978) *PLPSC9*, 1209. [6] Allen et al (1980) *GCA* 44, 685, [7] Fegley (1982) *LPSC XIII*, 211. [8] Tanaka et al (1979) *LPSX*, 1203. [9] Boynton (1978) *LPS IX*, 120. [10] Stolper et al (1982) *LPSC XIII*, 772. [11] Davis et al (1978) *PLPSC9*, 1235.

FIGURE 2

