DUSTY SILICATES IN UNEQUILIBRATED ENSTATITE CHONDRITES.

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Introduction: Olivine and pyroxene in chondrules that are not in equilibrium with the rest of the chondrule assemblage are often referred to as "relict" grains and have been described in numerous chondrules from ordinary and enstatite chondrites [e.g., 1-8]. They are interpreted to represent fragments from pre-existing chondrules and their discovery has led to the hypothesis of chondrule recycling during chondrule formation [e.g., 8]. One readily recognizable variety of these are FeO-rich olivine and pyroxene grains in type I (FeO-poor) chondrules that are characteristically filled with tiny (µm to sub-µm size) blebs of Fe-metal, referred to as *dusty grains*, suggesting reduction of Fe from the silicates during chondrule formation. Presence of such grains in enstatite chondrites led [3] to conclude that chondrules in the highly reduced unequilibrated enstatite chondrites (UECs) formed from more oxidized precursors. Here we present a detailed Field Emission SEM study of dusty FeO-bearing grains in the primitive Allan Hills (ALH) 81189 EH3 chondrite. The goal is to better understand the reduction history of the UECs, compare the dusty grains in UECs to those in UOCs and decipher the processes of oxidation and reduction in chondrites.

Results: We studied four dusty grains from thin section ALH 81189, 3 using the Hitachi S-4700 Field Emission Scanning Electron Microscope (FE-SEM) and the Cameca SX 100 electron probe at the AMNH. All of the grains studied occur in isolated lithic fragments. One has a partially curved outline suggesting it is a fragment of a chondrule-like object and the other 3 are completely angular. The dusty grains in these fragments are complex assemblages of olivine, low-Ca pyroxene, and silica with enclosed sub-micrometer sized blebs of Fe metal. In some cases, the grains are predominantly low-Ca pyroxene but generally contain small areas of olivine throughout. In some of the fragments the silica forms parallel aligned lamellar structures (~2 x 0.2 µm) and some of the Fe metal occurs in parallel strings of blebs (up to 0.3µm in size) distributed throughout the gains, suggestive of solid state reduction along crystallographic features. The fragments are also associated with large (~10 µm size) grains of silica within the fragment or on the fragment edges. Similar occurrences of reduction have been described in ordinary chondrites with some differences. Silica is associated with the dusty grains in ALH 81189 but has not been described in association with dusty grains in UOCs. Some of the larger silica grains associated with the fragments may not be a direct product of reduction alone and may be primary, possibly precipitated from an SiO-rich vapor.

Discussion and Conclusions: We suggest that the dusty grains in ALH 81189 formed from solid-state decomposition of FeO-bearing olivine through reduction of Fe (from Fe_2SiO_4) to form silica, pyroxene and Fe metal. Thus, some of the metal in the enstatite chondrites (and metal/silicate separation) may be a result of reduction of Fe from FeO-silicate. Enstatite chondrites differ from ordinary and carbonaceous chondrites in that olivine is not a dominant mineral. However, the finding of olivine in the dusty grains suggests that olivine may have once been more abundant in the enstatite chondrite-forming region than is currently present in the UECs. The dusty grains may represent material from an earlier generation of chondrules formed under more oxidizing conditions than are currently represented by UECs. The more oxidized FeO-bearing olivine and pyroxene in enstatite chondrites have oxygen isotope ratios similar to the FeO-poor enstatite that is characteristic of EH3 chondrites, indicating that they are closely related materials from the same reservoir [9,10]. A pre-history of more oxidizing conditions for the enstatite chondrites is supported by presence of FeO-bearing grains enclosed within low-FeO, type I chondrules [e.g., 7], and presence of Ti4+ in the enstatite chondrites [11]. It also suggests chondrule recycling for enstatite chondrite chondrules, similar to that proposed for ordinary chondrites [e.g., 8]. Thus, the enstatite chondrites record a pre-history of chondrule formation during oxidizing conditions followed by a change in the chondrule-forming environment to more reducing conditions. The latter may be due to an influx of carbon-rich material or vapor into the inner solar system region where the enstatite chondrites are thought to have formed.

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