TEM STUDY OF THE SUBMICROMETER-SIZED FRACTION OF MATRIX IN SAHARA 97072 (EH3) AND ALH 84170 (EH3). S. L. Lehner[1] and P. R. Buseck[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, (slehner@asu.edu, pbuseck@asu.edu).

Introduction: Enstatite chondrites (ECs) contain between 2 and 15 vol % matrix materials (grain diameters <~5 μm) [1, 2]. Recent work on EH3 chondrites shows ~50% of the matrix consists of submicrometer material inferred to be nebular fines [3]. We present here preliminary results from the first transmission electron microscopy (TEM) investigation of the submicrometer fraction of matrix in EH3 chondrites Sahara (SAH) 97072, which is one of the most primitive known enstatite chondrites [4], and ALH 84170. The mineralogy of the fine-grained material is similar to the coarser fraction.

Methods: Thin sections were first studied using reflected- and transmitted-light petrographic microscopy, SEM, and electron microprobe. Two slices 10 and 20 μm in length respectively were extracted from matrix areas using a focused ion beam (FIB) for study with TEM. Nine ion-milled sections from SAH 97072 were also studied with TEM and SEM. High-resolution imaging, electron diffraction, and EDS were performed using a JEOL 2010 transmission electron microscope.

Results: When viewed in combined transmitted and reflected light, matrix in thin sections appears brown and contains numerous clasts of opaque material and silicates [3] (Fig. 1). A FIB section from SAH 97072, extracted from a matrix area similar to that in Figure 1, contains silica, an amorphous silica-rich material with variable concentrations of Al and Ca, crystalline grains with clinopyroxene composition, dark particles which contain significant CaO, TiO_2, and Cr_2O_3 with either Si and Al, or Si and Mg as major elements, small spherules relatively transparent to the electron beam (light-colored), troilite, and a schreibersite grain not associated with Fe-Ni alloy (Figs. 2 and 3). A FIB section from ALH 84170 consists of enstatite containing Fe-rich veins that may represent terrestrial alteration. Light-colored spherules similar to those in Figure 2 also occur.

Transmission electron microscopy of ion-milled sections shows nm-sized mineral grains in both amorphous and finely crystalline silica-rich matrices. The matrix material contains either Al or Mg as major elements and Na or Ca as minor elements and in some areas it is simply silica (we are unsure of the mineral form and so use this generic name). Submirometer minerals include kamacite, troilite, niningerite, oldhamite, Cu-rich sulfide, schreibersite, enstatite, and silica. Spherules of kamacite and troilite are abundant near shock-melt veins having Fe-FeS eutectoid textures (Fig. 4). A spherule of enstatite containing kamacite-troilite inclusions hosted within Fe-Ni metal near a shock-melt vein may indicate shock-induced silicate melting (Fig. 5).

Discussion: Amorphous SiO_2-rich material whose composition does not match proportions in common minerals occurs in all submicrometer material we have investigated. SiO_2-rich mineral structures can be easily damaged by the electron beam, and therefore it is difficult to be certain that the amorphous material is primary, especially since shock can also cause amorphization. The Fe-FeS spherules (Figs. 4 and 5), common near shock veins are not present in the FIB sections. Nevertheless, the amorphous material in the SAH 97072 FIB section (Figs. 2 and 3) may be associated with shock.

Electron diffraction and dark-field imaging of the light-colored spherules in both FIB sections suggest they are crystalline. EDS results suggest some consist of silica whereas others have the same composition as their surroundings. Schreibersite particles separate from Fe-Ni metal, such as the one in the FIB section (Fig. 2) also occur in ion-milled sections. The occurrence of schreibersite separate from Fe-Ni metal is intriguing because it has been proposed to be an early condensate [5] and also to have exsolved from Fe-Ni metal [6]. The occurrence of free schreibersite is consistent with the former hypothesis.

Summary: The submicrometer fraction of EH matrix contains areas of both amorphous and extremely fine-grained SiO_2-rich material hosting submicron-sized clasts of minerals typical of the EH chondrites including schreibersite unassociated with Fe-Ni metal.

References: [1] Huss, G.R., et al (2005), in *Chondrites and the Protoplanetary Disk*, Astronomical Society of the Pacific, San Francisco, 701-731. [2] Scott, E.R.D. and A.N. Krot (2005), in *Chondrites and the Protoplanetary Disk*, Astronomical Society of the Pacific: San Francisco, 15-53. [3] Rubin, A.E., et al., (2009), MAPS, 44, 589-601. [4] Weisberg, M.K. and M. Prinz. (1998), LPSC XXIX Abstract # 1741. [5] Lin, Y. and A. El Goresy (2002), MAPS, 37, 577-599. [6] Kimura, M. (1988), Proceedings of NIPR Symposium on Antarctic meteorites, 1, 51-64.

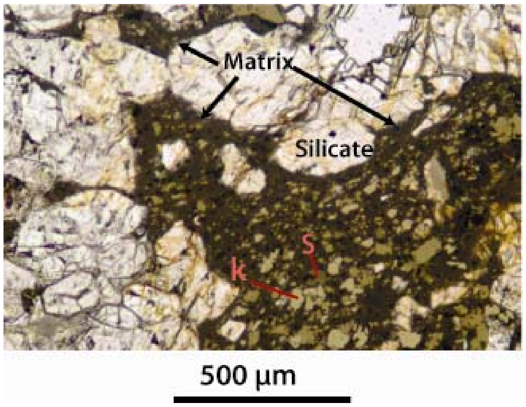

Fig 1. *Optical micrograph of SAH 97072 taken in combined transmitted and reflected light showing matrix (brown material) in an embayment of a porphyritic pyroxene chondrule. k – kamacite, s – sulfide.*

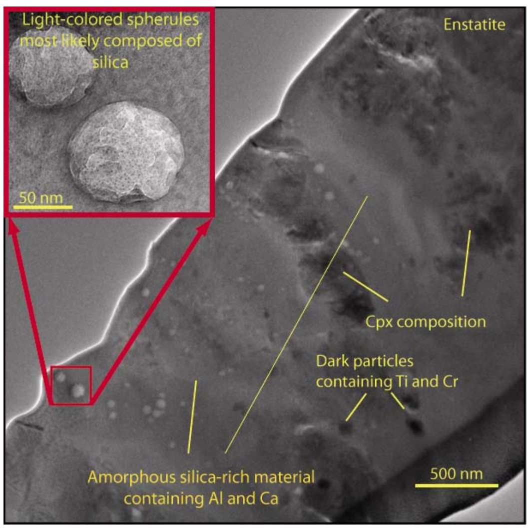

Fig 2. *TEM image of FIB section showing amorphous regions.The diffraction pattern indicates amorphous material hosting small particles. The inset shows unidentified spherules.*

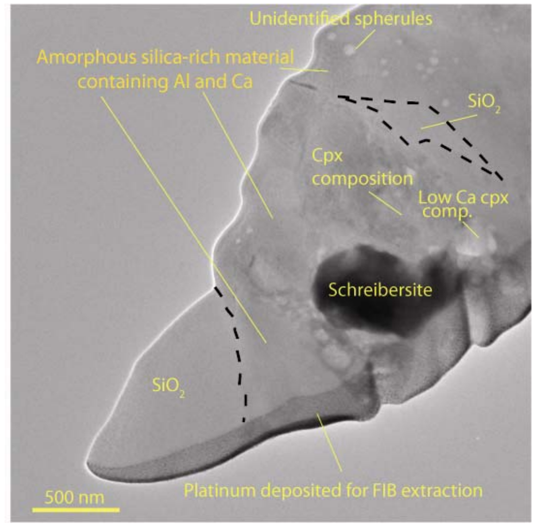

Fig. 3 *Another area of FIB section showing areas of SiO_2 and a schreibersite grain.*

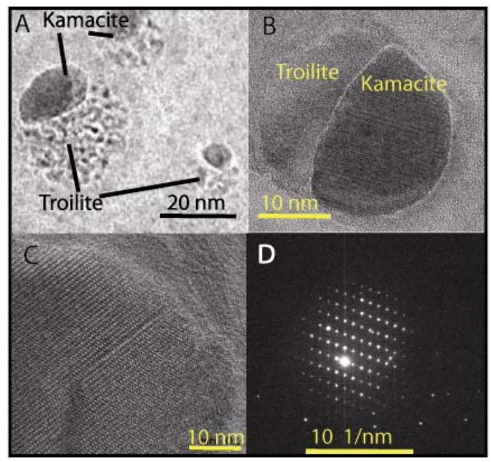

Fig 4. *A, B, and C are TEM images of kamacite-troilite spherules D. Kamacite diffraction pattern from C.*

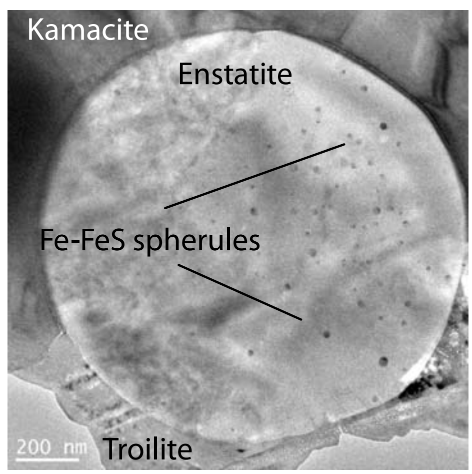

Fig 5. *Spherule of enstatite within kamacite and troilite. The enstatite spherule itself encases kamacite-troilite spherules.*