UNEQUILIBRATED, EQUILIBRATED, AND REDUCED AGGREGATES IN ANHYDROUS INTERPLANETARY DUST PARTICLES, J. P. Bradley, MVA Inc., 5500/200 Oakbrook Pkwy., Norcross, GA 30093

Track-rich anhydrous IDPs are probably the most primitive IDPs because a) they have escaped significant post-accretional alteration, b) they exhibit evidence of (nebular) gas phase reactions [1-3], c) their mineralogy is similar to comet Halley’s dust [4], d) some of them exhibit comet-like IR spectral characteristics [5]. However, basic questions about the mineralogy and petrography of anhydrous IDPs remain unanswered, because they contain aggregated components that can be heterogeneous on a scale of nanometers (Fig. 1). In some IDPs, aggregates account for >75% of the volume of the particle. The aggregates have been systematically examined using an analytical electron microscope (AEM), which provides probe-forming optics and (x-ray and electron) spectrometers necessary to analyze individual nanometer-sized grains. The AEM results reveal at least three mineralogically distinct classes of aggregates in anhydrous IDPs, with mineralogies reflecting significantly different formation/aggregation environments.

The IDPs studied are U219C2, U219C11, U220A19, U222B28, U230A3, W7027A11, and W7027H14. They were embedded, thin-sectioned, and examined using brightfield and darkfield imaging. Mineral compositions were measured using energy-dispersive x-ray spectroscopy (EDS) and electron energy-loss spectroscopy (EELS). Local solid state environments of specific elements within aggregates were investigated using energy-loss near edge structure analysis (ELNES) (Fig. 2) [5]. Crystallographic parameters of mineral grains were determined using lattice fringe imaging, selected area electron diffraction, and microdiffraction.

Three classes of aggregates were studied: unequilibrated, equilibrated, and reduced aggregates. Unequilibrated aggregates (UA’s) contain crystalline grains, typically between 1 and 40 nm diameter, embedded in non-crystalline material (Fig. 1). Bulk compositions of UA’s are approximately chondritic although sulfur is often significantly depleted [6]. The compositions of individual grains and (non-crystalline) matrix were investigated using EDS and ELNES. EDS analyses suggest that most grains contain either major Fe and minor Ni, or major Fe and S. Microdiffraction patterns confirmed that the grains are kamacite (FeNi) and FeS respectively. Figure 2 (column A) shows the O-K, Mg-K, Si-K, and Fe-L core scattering edges from an unequilibrated aggregate. Mg-K and Si-K edges from both crystalline and non-crystalline silicates are shown in columns B and C. Comparison of near edge structures for Mg and Si (columns A through C) suggest that most of the Mg and Si in the aggregate are within a non-crystalline environment (i.e. glass) rather than crystals. The near edge structure of the O-K edge (column A) is compatible with silicate glass or crystals, although there is evidence (arrowed) of oxides (e.g. magnetite) (see [7]). EDS analyses suggest that the non-crystalline matrix typically contains major Mg and Si, and sometimes Al, Ca, and Fe, although the matrix composition can vary significantly on a nanometer scale. Equilibrated aggregates (EA’s) exhibit distinct igneous textures and grain sizes between 0.1 and 0.5 μm. Olivine and pyroxene (with equilibrated Mg/Fe ratios), Fe-sulfides, and feldspathic glass are the most common minerals. Petrographic evidence suggests that EA’s may have formed from UA’s by melting and recrystallization, possibly in the solar nebula. Reduced aggregates (RA’s) contain FeNi metal, FeNi carbides, and Fe-rich sulfides embedded in carbonaceous material. The FeNi carbides and carbonaceous material may have formed by catalytic reactions between FeNi metal and carbon-containing gas (e.g. CO) [2]. RA’s may contain organic carbon.

In summary, anhydrous IDPs contain at least three types of aggregates. On a scale of <0.1 μm, glass is the predominant silicate in anhydrous IDPs, and the abundance of glass suggests a possible link between aggregates in anhydrous IDPs and IR silicate emission from comets and interstellar grains [4]. Kamacite, which is rare as large grains, is the most abundant nanometer-sized grain in UA’s. Metallic Fe provides further evidence for the survival of high temperature condensates in anhydrous IDPs [1, 3, 8, 9].
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References

Figure 1. Darkfield micrograph of unequilibrated aggregates in IDP U22019.

Figure 2. Column A - O, Mg, Si, and Fe energy-loss core scattering edges from an unequilibrated aggregate. Column B -- Mg-K edges in crystalline silicates and glass. Column C -- Si-K edges from crystalline silicates and glass.