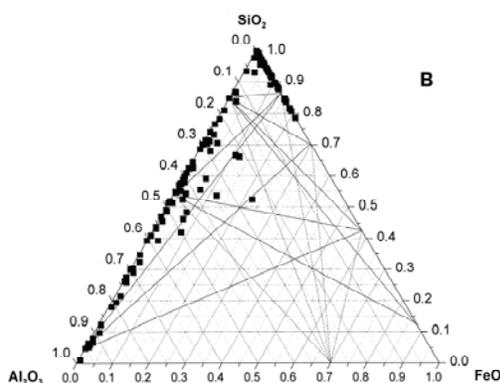


**DEEP METASTABLE EUTECTIC CONDENSATION IN LOW-SILICA Al-Fe-SiO-H<sub>2</sub>-O<sub>2</sub> SMOKE: SIMPLE EXPERIMENTS, MAJOR IMPLICATIONS.** Frans J. M. Rietmeijer<sup>1</sup>, Aurora Pun<sup>1</sup> and Joseph A. Nuth<sup>2</sup>, <sup>1</sup>Department of Earth and Planetary Sciences, University of New Mexico, MSC03-2040, Albuquerque, NM 87131-0001, USA (fransjmr@unm.edu), <sup>2</sup>Astrochemistry Branch, Laboratory for Extraterrestrial Physics, Code 691, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

**Introduction:** Laboratory vapor phase condensation experiments conducted to simulate kinetically controlled condensation in natural environments, such as a cooling solar nebula, have shown important aspects of fundamental behavior, *viz.* (1) simple metal-oxide condensates are crystalline, (2) condensed dust that is a mixture of two or more metal-oxides are unfailingly amorphous solids, and (3) such chemically complex solids have distinct and unique deep metastable eutectic (DME) compositions [1,2]. These non-equilibrium DME compositions are predictable from the binary phase diagrams, which means they become in fact predictable with regard to their approximate compositions. In a ternary diagram of simple oxides the (binary) DME compositions plotted along the sides of the diagram become the end-members of mixing lines that – in their turn – define the preferred compositions for ternary solid compositions (Fig.1).



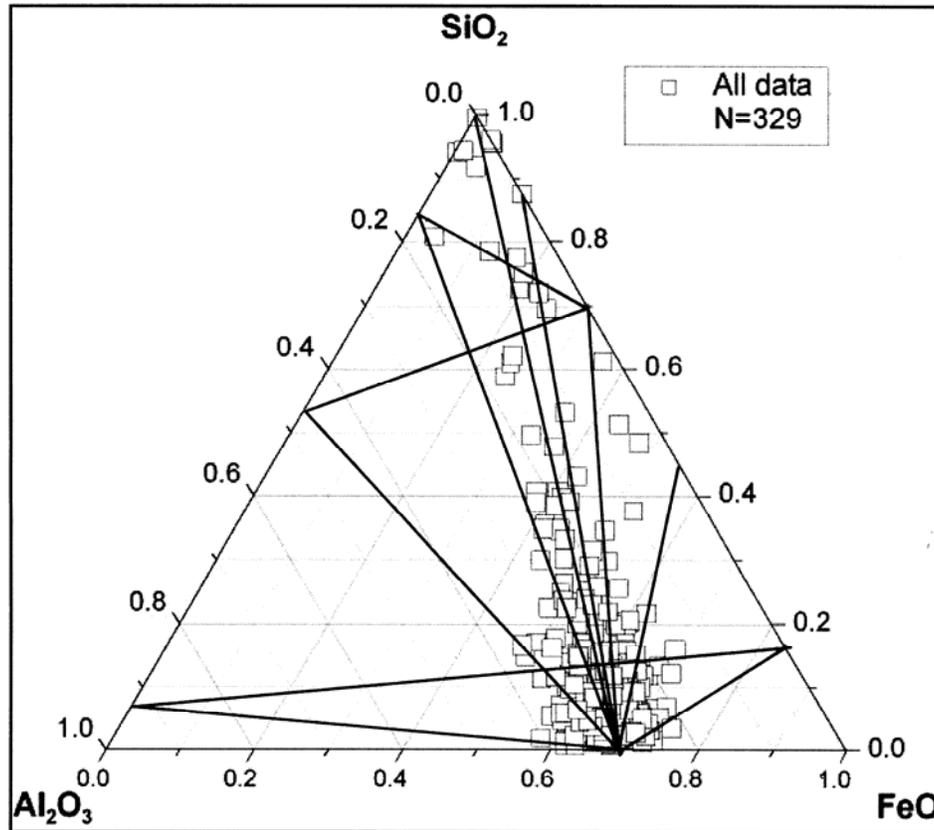
**Figure 1:**  $Al_2O_3$ - $FeO$ - $SiO_2$  diagram showing the individual grain compositions condensed in an Al-Fe-Si-O<sub>2</sub>-H<sub>2</sub> vapor and could grow along the experimentally verified solid mixing lines. Compositions along the dotted lines would require a DME point with a composition indicated on the  $Al_2O_3$ - $FeO$  side to provide the dashed mixing lines. Reproduced from ref. [2].

The predicted DME dust compositions and corresponding mixing lines for experimentally verified behavior of Mg-Fe-Si-O<sub>2</sub>-H<sub>2</sub> vapor condensation match exactly the amorphous Mg-rich ferromagnesian silicate grains (~500nm in size) in the matrix of aggregate interplanetary dust particles (IDPs) [3].

The physical conditions leading to DME dust formation are both high heating and high cooling rates that are not limited to vapor condensation but occur also in fulgurites [4], coal fly-ash formation and during hypervelocity impact. We would predict that some of the silicate compositions in STARDUST aerogel were the result of the same physical conditions that lead to formation of DME solid compositions during melting of aerogel and Wild dust. Amorphous silicate materials were found in aerogel [5,6] some of which had a DME ferromagnesian silicate composition [6].

**Experimental conditions:** The smoke was condensed using the same Condensation Flow Apparatus we have used before; for details see [1]. In general, smoke particles condense from a gas at nearly room temperature after passing through a hydrogen oxygen flame. The gas composition is typically more than 80% hydrogen with variable amounts of silane, iron pentacarbonyl (in helium) and trimethyl aluminum (in helium) added, as appropriate to the experiment. The gases are mixed thoroughly by passing through a chamber filled with glass beads prior to injection into the furnace. The furnace is a resistively heated alumina tube maintained at constant temperature, typically 775K, where the reactive gas stream is mixed with oxygen at controlled flow rates to produce a hydrogen flame from which the dust particles condense after emerging from the furnace.

**Results:** The compositions of 329 individual, mostly rounded grains with an average grain size of 9.1 nm are plotted in Fig. 2. All grains are amorphous. They condensed and grew in a vapor with a  $Al_2O_3 = 25.8$ ,  $FeO = 59.3$  and  $SiO_2 = 14.9$  wt% bulk composition that is the average of condensed grains but it may slightly underestimate the bulk silica content. The condensed grains don't have random compositions that are stretched between the  $SiO_2$  apex and a Fe-rich Al-Fe-O phase. The condensed grain compositions put this DME phase at  $FeO = 70$  wt%; matching the predicted point in Fig. 1. From this point mixing lines emanate to other DME compositions (*cf.* Fig 1) in a manner that accounts for the entire distribution of data points in Fig.2. We note that the  $Al_2O_3$ - $FeO$  phase diagram allows only one DME at the location where it was experimentally determined.



**Figure 2:**  $Al_2O_3$ - $FeO$ - $SiO_2$  diagram with 329 individual grain compositions (open squares) condensed from an iron-aluminate vapor with low  $SiO_2$  probably as  $SiO$  and  $Si_2O_3$  vapor molecules. The iron oxidation states were not buffered; it is a mixture of  $FeO$ . $Fe_2O_3$  [2]. The solid mixing lines from this confirmed DME composition are shown.

**Discussion:** With experimental results here presented we have now completely established all DME points and mixing lines in the  $Al_2O_3$ - $FeO$ - $SiO_2$  and  $Al_2O_3$ - $MgO$ - $SiO_2$  systems that include most of the common Mg,Fe-aluminosilicate minerals. We have made a start condensing refractory smokes containing CaO [7] and once this set of experiments is completed the DME compositions possible in the systems for most rock-forming minerals will be known.

Such phases will include the amorphous Mg,Fe,Ca-aluminosilica grains that occur in chondritic aggregate IDPs [cf. ref. 3] and those that were already found in aerogel [5] and those yet to be identified. Massive (*i.e.* non-vesicular) aerogel forms a partial rim on silicate minerals where it has a continuous compositional gradient between the mineral and vesicular aerogel matrix [6]. A complete, glassy rim with a DME composition is present around some GEMS-like objects [6]. The composition of this rim is evidence for rapid heating and rapid cooling of a (superheated?) ferromagnesian-silica melt. The compositional gradient is NOT defined by DME compositions suggesting that no superheated (?) melt was involved but that a solid-state dif-

fusion-controlled process across an initially very steep chemical gradient may have been.

**Conclusions:** Amorphous solids with recognizable deep metastable eutectic compositions in STARDUST aerogel, or a lack thereof in amorphous silicate materials, can be used to define the nature of local processes between Wild dust and aerogel.

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