Deep metastable eutectic condensation in Al-Fe-SiO-H₂-O₂ vapors: Implications for natural Fe-aluminosilicates

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ABSTRACT

Vapors of Al-Fe-SiO₂-H₂ having two different compositions produced ferroaluminosilica grains as a function of agglomeration and fusion along mixing lines in the Al₂O₃-FeO-SiO₂ system that are defined by the predictable, deep metastable eutectic (DME) compositions of the smallest condensate grains. Disorder of these amorphous grains is higher than in quenched glass of identical composition, which is the very property of dissipative structures (Prigogine 1978, 1979) that are states of organization of matter where disequilibrium becomes a source of order. Iron-oxidation states control ferrosilica condensate compositions. We present the first magnetic measurements showing a high Fe³⁺ content in condensed ferrosilica grains. The Fe-cordierite grain composition is primarily the result of predictable non-equilibrium condensation, not the bulk gas phase composition. Natural terrestrial and anthropogenic (e.g., smelters, coal fly ash) Fe-cordierite might well be a metastable phase due to kinetically controlled processes. Amorphous Mg₂Fe-bearing aluminosilica dust in chondritic interplanetary dust aggregates and (rare) Mg₂Fe-aluminosilicates in meteorites might have condensed via similar processes.

Keywords: Vapor phase condensation, ferroaluminosilica vapor, non-equilibrium condensation, deep metastable eutectics, magnetic measurements, Fe-cordierite

INTRODUCTION

Planetary materials, as described in the Reviews in Mineralogy volume edited by J.J. Papike (1998), are fundamentally the result of dust aggregation. An axiom of cosmochemistry holds that dust or its precursor was initially condensed from an O-rich, Si-bearing vapor. Once formed, the condensed solids could then be processed in molecular clouds and circumstellar disks such as in the solar nebula 4.56 billion years ago. Understanding the condensation process is critical to appreciate the properties of the nanometer-sized condensed solids that ultimately de...