Melting of Sahara 97072 Meteorite at High Pressure and High Temperatures

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Introduction: The large range of oxygen fugacity values measured from meteoritic materials indicates the diversity of materials found in the solar nebula[1]. The oxidation state of the materials from solar nebula is a critical parameter in determining the planetary formation and differentiation in the early solar system. Based on partial melting experiments on Allende CV3 carbonaceous chondrite, Agee (1990) proposed an early stage differentiation model of the Earth with a FeO-rich magnesiowüstite layer in the deepest levels of the Earth's interior and a proto-core rich in sulfur (13 wt%) and oxygen (12 wt%). As Agee suggested, the maximum content of sulfur and oxygen in the proto-core could be balanced if the model was modified with some enstatite chondrites[2]. This is because enstatite chondrites are undifferentiated meteorites and among the most reduced material with an average total iron content of 29 wt% [3]. In addition, because their isotopic composition is identical to the Earth, enstatite chondrite was also proposed as primary materials for the Earth formation[4]. And the enstatite chondrite model fit with one of the proposed formation mechanisms of the Earth: the original subjects (building block) of the Earth were highly reduced, Fe-metal and ferrous iron were extracted from silicate crystalline after partial melting at subsolidus temperatures, and the metallic liquid segregated to the core by percolation through a solid silicate matrix. There are obstacles to an enstatite chondrite model of the Earth's bulk composition. For example, enstatite chondrites are depleted in refractory elements comparing with the Earth's primitive upper mantle[5], and the proto-core forming mechanism that the metal iron and ferrous iron segregating from silicate cannot operate in the system which has same oxygen fugacity as today's Earth mantle.

In order to derive constraints on the formation of terrestrial planets from enstatite chondrites and to test the possible effect of volatile element on melting interval of sulfide and silicate, we have conducted a series of melting experiments on the Sahara 97072 (EH3) meteorite at 5 GPa and 1000-1700°C by using multi-anvil apparatus. Starting material of natural Sahara 97072 meteorite was used for all the experiments. The bulk composition of Sahara 97072 used in this study is similar but not identical to the composition reported by Lehner et al. (2014)[6]. For each experiment, machined double graphite capsules were chose as sample container because graphite has high melting temperature and allows an effective control of the oxygen fugacity, which make them good container to keep the reduce condition during heating. This study reports the melting relations at 5 GPa and variable temperatures: (1) (Fe, Ni)-sulfide melt completely at 1200°C; (2) silicate partial melting begins at 1400°C, and quenched sample shows immiscibility between (Fe, Ni)-sulfide melt and FeO-rich silicate melt. and (3) the Sahara 97072 meteorite is completely melted when temperature is reaching 1600°C. At 5 GPa, both pyroxene and olivine appear to be stable near the liquidus, indicating that 1600°C and 5 GPa is very close to the pyroxene-olivine cotectic.

By overheating the Sahara 97072 meteorite sample to 1650 and 1700°C, (Fe, Ni)-alloy saturated from (Fe, Ni)-sulfide. The spherical shape of the (Fe, Ni)-alloy indicates that the lost of sulfur to the silicate melt happened during melting rather than quenching. The silicate liquid at overheating conditions show less FeO content than the completely melt condition, indicating that FeO was partially reduced back as Fe-alloy. EPMA measurement results show that about 3 wt% C was dissolved in (Fe, Ni)-alloy, which caused the sample reached the metallic liquid immiscibility gap between Fe-C and Fe-S phases as showed by previous study[7].The overheating experiments on Sahara 97072 suggest that the relatively small planetary bodies with elevated sulfur and carbon content would have likely experienced sizable core stratification during early melting event.

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