A POTENTIAL STRATIFICATION OF THE CORE OF MARS CAUSED BY HYDROGEN. H. Piet\textsuperscript{1}, K. Leinenweber\textsuperscript{1}, E. Greenberg\textsuperscript{2}, S. Chariton\textsuperscript{3}, V. B. Prakapenka\textsuperscript{2}, P. R. Buseck\textsuperscript{1}, and S.-H. Shim\textsuperscript{1}
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Abstract: We study the phase relations in the Fe-S-H system under pressures and temperatures relevant to the Martian core. We find that H-bearing alloys and S-bearing alloys would be immiscible in the core of Mars potentially causing its stratification.

Introduction: The Earth’s core mainly consists of an iron-nickel alloy enriched with light elements [1]. Candidate light elements are silicon, oxygen, sulfur, carbon and hydrogen given their natural abundance and solubility in core-forming materials [2]. Geophysical observables, such as density, provide us with some constraints on the amount of light elements in the core. However, the abundance of each light element in the core remains a matter of debate.

In the case of Mars, geophysical constraints are limited and its core density remains to be constrained. However, given the nature of core formation, it is likely that the core of Mars (just like Earth’s core) contains light elements as well. From SNC meteorites, there is strong evidence that sulfur is a major alloying component in the core of Mars, with an estimated abundance around 3-15% [3].

Hydrogen is the most abundant element in the solar nebula from which planets accreted. As such, it is important to consider its presence in the interior of planets, including cores. However, this element has not received the appreciation of other light elements in the study of Earth’s core composition because of i) its high volatility and ii) the challenges associated with its experimental study. Recent experimental developments have highlighted that hydrogen’s affinity for metals is strongly enhanced with pressure [4, 5]. Core formation being a high-pressure process [6], it is therefore possible for planetary cores to incorporate a significant amount of hydrogen during their formation.

In this study, we investigate phase relations in the Fe–S–H system at the pressures and temperatures relevant to the Martian core. We then discuss the potential geophysical implications.

Experimental methods: To simulate the high pressures and temperatures in the core of Mars, we use the laser-heated diamond anvil cell. Samples of Fe\textsubscript{3}S, FeS or FeS\textsubscript{2} compositions were loaded into the sample chamber together with H\textsubscript{2} gas using a hydrogen gas loading facility at ASU. First, we compressed the diamond-anvil cell to target pressures ranging between 28 and 50 GPa. To reduce diamond anvil embrittlement from hydrogen, we then conducted pulsed laser-heating to temperatures in the 1000–3100 K range. Phase identification was performed at in-situ high pressure and high temperature using synchrotron X-ray diffraction at the GSECARS sector of the Advanced Photon Source.

Phase relations in the Fe-S-H system and implications for Mars core: Upon heating at high pressure, we observed the formation of separate iron sulfide and iron hydride phases, e.g. FeS + H\textsubscript{2} = Fe\textsubscript{3}S + FeS\textsubscript{2} + FeH\textsubscript{2}. The same behavior is observed for FeS\textsubscript{2} + H\textsubscript{2} and FeS + H\textsubscript{2} as well. Measured unit-cell volumes of the phases suggest that hydrogen is not incorporated into iron sulfides, and the amount of sulfur in hydride should be very low. We observed the formation of FeH\textsubscript{2} at pressures as low as 27 GPa, which may require a small amount of S in the structure of FeH\textsubscript{2} since S-free FeH\textsubscript{2} does not form below 67 GPa [4].

In the Fe\textsubscript{3}S + H\textsubscript{2} system – the most relevant to Mars core composition – we observed the formation of FeS and FeH upon heating, similarly to more sulfur rich compositions. We also found the formation of a new phase with a crystal structure similar to that of FeH\textsubscript{2} but with a significantly bigger volume. Our data suggest that the new phase might be a more Fe-rich phase than Fe\textsubscript{3}S. Its structure, however, remains to be resolved.

The formation of separate FeS and FeH phases at pressure and temperature relevant to the Martian core suggests immiscibility of FeS and FeH alloys. The density difference between light H-bearing alloys and heavier S-bearing alloys could lead to a stratification of the core. Such stratification could influence the strength and scale of convection in the core, providing a potential mineralogical explanation for the early shutdown of Mars geodynamo [7].

References: