**Introduction:** In the early Earth or Mars, S was accreted mostly as iron sulfides, either from interplanetary dust, chondrites or small planetary bodies. The first melt to percolate through the surrounding silicates during planet differentiation was a Fe-S melt because of the low eutectic melting temperature of the Fe-FeS system [1-3]. Si could not dissolve into the iron sulfide melt because the Fe-Si system presents an extensive liquid immiscibility field at ambient pressure. The simultaneous presence of S and Si in planetary cores was therefore rejected on the basis of such melting behavior in the system. The purpose of this study is to examine whether or not the miscibility gap persists in the Fe-Si liquid system at high pressure. We report melting experiments in the Fe-Si system conducted in a multi-anvil apparatus at pressures between 10 and 27 GPa and temperatures up to 2343 K. The experiments document the change of melting relations in the system with increasing pressure. The results have important implications for the differentiation processes of the planets and the composition of their cores.

**Experimental Procedures:** Experiments were performed in a 1500-tons multi-anvil apparatus using an 8/3 cell assembly [4]. Starting material was obtained by mixing pure FeS and Fe-17wt%Si powders. Its chemical composition is Fe-18.5wt%S-8wt%Si. The starting material was loaded in a hBN container to avoid any oxidation reaction or chemical contamination, which would have happened with either a MgO or a metallic capsule (Fe-alloy formation). For each experiment, sample was pressurized at room temperature to the target pressure and then heated to the desired temperature at a rate of 75 K/minute. Because equilibrium can be achieved within a couple of minutes in the liquid state for Fe-alloys [5], sample was kept at high temperature for 5 minutes. Short run time is critical to avoid oxygen diffusion from the cell-assembly (MgO octahedra and LaCrO₃ sleeve). All samples were recovered, mounted in epoxy, mechanically polished, and analyzed with a JEOL8900L electron microprobe. Melt compositions were obtained by scanning a 50 μm x 50 μm area.

**Experimental Results:** We conducted series of experiments between 10 GPa and 27 GPa over a wide temperature range from 1673 K to 2343 K. Melting relations were interpreted on the basis of quenched textures and chemical compositions of phases. A quench texture with Si-rich and S-poor droplets dispersed in a Fe-S liquid is interpreted as evidence for two coexisting liquids, whereas dendritic texture with homogeneous distribution of dendrites indicates complete liquid miscibility. The change of melting relations as a function of pressure is illustrated in Figure 1.

![Figure 1. Melting relations for a composition of Fe-18.5wt%S-8wt%Si at high pressure and temperature. The solidus curve separates the solid phase assemblages (solid squares) from the solid-liquid assemblages (open squares with crosses). The liquidus curve is drawn between the solid-liquid assemblages (open squares with crosses) and liquid. The dashed line divides the two-liquid region (open circles) and the one-liquid region (open squares).](image-url)

At ambient pressure, an extensive liquid immiscibility field exists in the Fe-Si system. This liquid immiscibility field persists at 10 GPa and 12 GPa, based on the observed quenching textures. At 10 GPa, the samples are completely molten at temperatures above 1823 K with quenching texture characterized by droplets of Fe-Si liquid in a Fe-S melt matrix. The Fe-Si(S-poor) droplets dispersed in a Fe-S(Si-poor) liquid have variable diameters, ranging from few microns to about 100 microns. At the maximum temperature investigated, 2343 K at 10 GPa, the compositions of the two immiscible liquids are Fe-2.7wt%S-12.8wt%Si and Fe-28.5wt%S-
that equally phase(s) systematically 15 dendrites incongruently. The system pressure FeS K, respectively, at 27 GPa. Fe-S texture, temperature, wt%Si) experiments understand system similar homogeneous liquid and systems. Two new Fe-S high-pressure phases, FeS2 and FeS, in the Fe-FeS system were found at pressures above 14 GPa [2] and above 21 GPa [3], respectively. Melting relations in the Fe-FeS system change significantly at about 14 GPa, from a simple binary eutectic system to a binary system with an intermediate compound which melts incongruently. In our 10 GPa and 12 GPa experiments, the Fe-S liquid is quenched as FeS dendrites in a Fe-FeS eutectic intergrowth, whereas at 15 GPa and higher, the Fe-S liquid is quenched as a very fine mixture of FeS and FeS2 grains. FeS2 is systematically present in samples quenched from miscible liquid. Because the short-range order in liquids depends on the structure of the solidus phase(s) [6], FeS2 could strongly modify the properties of the Fe-S liquid so that silicon becomes equally soluble in both Fe-Si and Fe-S liquid, and consequently, the miscibility gap would be closed.

Implications: Our experimental results indicate that the miscibility gap in the Fe-S-Si system closes at high pressure. The results have important implications for the formation of planetary cores and their chemical compositions. If the size of the planet is such that the maximum pressure encountered was below 14 GPa during its differentiation, then silicon is unlikely to be a light element of its core, but sulfur is likely to be present in large quantities. Ganymede and Mars could well be in this category of "low-pressure" differentiated planets. Geochemical models of Mars predict sulfur content in the Martian core between 14wt% and 16 wt% [7, 8]. Ganymede has an internal magnetic field, which implies a liquid core. The composition of Ganymede's core is probably close to a eutectic composition (Fe-25wt%S at 4-8 GPa), that does not require very high temperature to maintain molten core.

Temperature of the proto-Earth is not well constrained, ranging from 2000 K to 3000 K. From electrical conductivity measurements on a mixture of 5vol% molten Fe-S and 95% olivine, it was argued that small bodies are expected to have formed cores very early [9]. These differentiated small bodies would have then contributed to the accretion of the proto-Earth. Such low-pressure differentiation mechanism requires relatively low temperature (less than 2000 K) (e.g., [10]). At this stage, Si is unlikely to have been alloyed to Fe-S melt, because of the existence of the liquid miscibility gap at low pressures. The excess of siderophile elements in the mantle requires an additional high-pressure differentiation step, estimated at pressures above 25 GPa and 2400 K [11]. Under those pressure and temperature conditions, the Fe-S-Si liquid miscibility gap is closed and Si could be dissolved in a Fe-S melt formed at a lower pressure. The high-pressure differentiation process could be consistent with a low oxygen fugacity environment, required for Si to be dissolved in liquid Fe [12, 13].