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Transcrystalline Migration of Metallic Melt in (Mg,Fe)O: Implications for the Core-Mantle Interaction

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Penetration of metallic materials has been invoked at the core-mantle-boundary to explain relatively strong magnetic coupling and some geochemical signature of core materials. However, all previously proposed models fail to explain an extensive penetration (10s of km) required to explain these phenomena. We report a discovery of a new process of metallic melt entrainment into the mantle minerals that might provide a clue to explain inferred extensive core-mantle chemical interaction.

When a mineral and molten metal co-exist at a large scale, the chemical equilibrium is attained only near the interface and the bulk of the system is out of equilibrium. Under these conditions, the gradient in chemical potential exists and the interface between these two phases becomes unstable against some morphological perturbation and one phase may penetrate into another. We found that such a process occurs between (Mg,Fe)O single crystal and molten metals (Mo-rich and Fe-rich metals). When such a system is annealed, morphological instability occurred and the interface became serrated. The serrated region grew and pinched off to become an isolated metal-rich blob. These blobs migrate into a crystal with the speed much faster than expected by diffusion-controlled processes. For example, after annealing at P=15 GPa, T=2000 K for 2 hours, a whole $\sim$1 mm size (Mg,Fe)O was penetrated by metallic blobs. The morphological instability of such an interface was explained by a theory of Mullins and Sekerka (1963, 1964). On the bases of their theory, we developed a model to explain the evolution of a metal-rich layer. In this model, the compositions of both migrating metallic blobs and surrounding mineral will change as a metallic blob migrates, and the migration will terminate when the composition becomes the equilibrium composition. Our model predicts that such a metal-rich layer could extend 10s of km at the core-mantle boundary but the nature of such a layer depends on the properties of mantle minerals and will differ among different planets with different mineralogy.