Europa’s structural conditions for the existence of subsurface ocean and the absence of metallic core-driven magnetic field

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Measurements of the magnetic field environment by the Galileo spacecraft during flyby of Europa detected an inductive magnetic signal generated by the response of Europa's interior conductors to temporal variations in Jovian magnetic field. On the other hand, no magnetic field originated from the dynamo motion in the metallic core. These measurements strongly suggest that a global subsurface ocean with electrolytes exists beneath the solid ice shell and that convective motion is not occurring in the metallic core.

The interior of Europa, which has a surface radius of 1565 km, is expected to be divided into metallic core, rocky mantle, and water layers based on the moment of inertia factor estimated from gravity field measurements (0.346 ±0.005 normalized by Europa’s radius and mass). Specifically, the thickness of the outermost water layer is 120-170 km, and the radius of the metallic core is 0.11-0.43 Europa’s radius. Within this possible range for the internal structure and uncertainty of material properties (especially the ice properties), no systematic investigation of Europa's internal evolution has been done that can explain the current state of the subsurface ocean and the absence of a core dynamo metal field.

Here, we perform a numerical simulation of the long-term thermal evolution of the Europa’s interior, and investigate the temporal changes of the ocean thickness and the temperature and heat flow of the metallic core. With various structures, e.g., metallic core density and radius, and thickness of water layer, and with various ice viscosity and tidal heating rate, we find the reasonable parameter ranges which are consistent with estimate of the ice shell thickness and the absence of convection in the metallic core. Current ice shell (ocean) thickness mainly controlled by the melting point viscosity of the ice and the tidal heating rate, and it does not depend on the difference in the thickness of the entire water layer. The thermal history of the metallic core is controlled by the entire thickness of the water layer and the metallic core density (thus the metallic core radius and the mass of the rocky mantle), and is not affected by difference of the ice shell (ocean) thickness. For the metallic core, there is no solution that satisfies both the melting and cooling conditions. Assuming Fe-FeS alloy core, the core could be molten without convection if the core composition is near the eutectic, or not molten (and no convection) if the composition is near the Fe or FeS end-member.

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