Floating-zone growth of single-crystal olivine $(Mg_{1-x}Fe_x)_2SiO_4$

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The olivine minerals $(Mg_{1-x}Fe_x)_2SiO_4$ are major components of the Earth's upper mantle. A series of solid solutions extending from Mg_2SiO_4 (forsterite) up to Fe_2SiO_4 (fayalite) can be formed in $(Mg_{1-x}Fe_x)_2SiO_4$ olivines. At certain pressure and temperature in the upper-mantle, an olivine-to-spinel transition occurs in $(Mg_{1-x}Fe_x)_2SiO_4$ olivines. The main discontinuity observed at 410km depth inside Earth in seismic wave velocities, density and electrical conductivity is commonly attributed to the olivine-to-spinel transition. Compared to the indirect measurements of mantle properties, the synthesis of high-quality single crystals of $(Mg_{1-x}Fe_x)_2SiO_4$ olivines should shed light on the formation mechanism, structure evolution, and physical properties of the upper mantle, in particular the anisotropic behavior. On the other hand, the physical and chemical properties of olivines are potentially attractive. For example, the olivines have been proposed as a potential cathode material for rechargeable magnesium batteries. Previously, several works had been done on the growth of olivine crystals by the Czochralski and floating zone methods.

In this study, olivine crystals $(Mg_{1-x}Fe_x)_2SiO_4$ have been grown by using a laser floating zone technique under different atmosphere, forming gas N_2(95%)-H_2(5%) and Argon, as well as at different growth rates 2, 5, 10 mm/h, respectively. The seed and feed rods were made of the natural olivine mineral with a composition of $(Mg_{0.93}Fe_{0.07})_2SiO_4$. A black powder was evaporated during the growth in both forming gas and Argon atmosphere. The x-ray diffraction measurements reveal that the black powder contains $FeSi_3$ compound. It was found that more $FeSi_3$ powder was generated under the forming gas, while the obtained crystals show a light green colour closer to aquamarine and good transparency. Under Argon gas, the crystals are dark green, more characteristic of natural olivine. The change of colour as well as the reduced loss of FeSi3 with argon can be explained by the higher reducing potential of forming gas. In addition, the obtained crystals have good transparency in the initially crystallized part from 0 to 1.5 cm, whereas crystals are less transparent at the later stages of the growth. It is suggested that the cracks and grain-boundaries as they continue to overlap in the growth of the crystal are responsible for the limited transparency of the later growth in the crystallized rod.