New insights into the solid transformation of ilmenite-hematite solid solutions

WEI TAN[1] HONGPING HE[2] CHRISTINA YAN WANG[3]

[1]511 Kehua Street, Guangzhou 510640, China. Email address: tanwei@gig.ac.cn
[2]511 Kehua Street, Guangzhou 510640, China. Email address: hehp@gig.ac.cn
[3]511 Kehua Street, Guangzhou 510640, China. Email address: wang_yan@gig.ac.cn

Hematite ($Fe^{3+}_2O_3$)-ilmenite ($Fe^{2+}TiO_3$) solid solution (Ilm-Hem_{ss}) forms in a wide range of temperature and oxygen fugacity due to the substitution of $2Fe^{3+} \rightarrow Ti^{4+} + Fe^{2+}$. Ilm-$Hem_{ss}$ plays important roles in geomagnetism and petrology studies. Previous studies suggested Fe^{3+} would exsolve from Ilm-Hem_{ss} and form hematite with the decrease of temperature. However, two enigmatic intergrowths, (i) magnetite lamellae and (ii) magnetite + rutile symplectite, occur in the host ilmenite from different petrological portions of the Xinjie intrusion, SW China. The special intergrowths are ideal to investigate the factors controlling the solid-transformation of Ilm-Hem_{ss} and the complex sub-solidus Fe-Ti oxides re-equilibration. The exsolved magnetite lamellae in the ilmenite contain nearly pure Fe_3O_4 with ~1 wt% TiO_2 and exhibit an crystallographic orientations, $\{111\}_{Mag}$ // $(0001)_{Ilm}$ and $<110>_{Mag}$ // $<10\text{-}10>_{Ilm}$, in the host ilmenite. The Fe^{2+} in the magnetite lamellae are probably derived from adjacent titanomagnetite by sub-solidus inter-oxide cation repartitioning of $Fe^{2+} + Ti^{4+} = 2Fe^{3+}$ on cooling. For the symplectitic intergrowth of magnetite + rutile, the crystallographic relationship with the host ilmenite is $\{111\}_{Mag}$ // $\{100\}_{Rut}$ // $(0001)_{Ilm}$ and $<110>_{Mag}$ // $<001>_{Rut}$ + $<101>_{Rut}$ // $<10\text{-}10>_{Ilm}$. The crystallization of rutile in the symplectite is probably formed by oxidation of Ilm-Hem_{ss} and triggers the transformation of Ilm-Hem_{ss} into magnetite + rutile symplectite. Our studies suggest that Ilm-Hem_{ss} tends to exhibit different types of exsolution with different T-fO_2 cooling trends trend primarily controlled by the factors such as original oxygen fugacity of the host rock, relative abundance of titanomagnetite and ilmenite, and composition of fluids.

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