American Mineralogist, Volume 85, pages 980–986, 2000

The transformation of andalusite to mullite and silica: Part I. Transformation mechanism in $[001]_A$ direction

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ABSTRACT

The high-temperature transformation of andalusite ($Al_2O_3{\cdot}SiO_2$ = A) single crystal to 3:2-mullite ($3Al_2O_3{\cdot}2SiO_2$ = M) and non-crystalline silica (SiO_2) taking place between 1500 and 1600 °C was investigated by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Electron diffraction studies confirmed the topotactical orientation relationship ($[100]_A \parallel [010]_M$, $[010]_A \parallel [100]_M$, $[001]_A \parallel [001]_M$) between the primary product (A) and the product phase (M), which was predicted by Pannhorst and Schneider (1978) on the basis of single-crystal X-ray diffraction studies. The transformation starts at the $(001)_A$ surface and proceeds rapidly along to the $c_{A,M}$-axis. The overall reaction front is parallel to (001) of andalusite and mullite, though on the microscopic scale it exhibits a zigzag shape with facets parallel to $\{011\}_A$ and $\{201\}_M$. The development of $\{011\}_A$ and $\{201\}_M$ microfacets is favorable, because both lattice planes exhibit a small misfit, which is close to zero at the transformation temperature. The undistorted and direct transition from andalusite to mullite and the high velocity of the reaction along $[001]_A$ suggests that the AlO_6 octahedra which occur in both structures are being preserved during the transformation. Other structural units, however, have to be decomposed and reconstructed. The newly formed mullite crystallites display an acicular shape elongated to the *c*-axis with an average size of about 250 nm along their small dimension. Excess non-crystalline SiO_2 is exsolved between the mullite crystallites in small channels running parallel to $[001]_M$. The major amount of the exsolved silica liquid is transported to the (001) surface of the former andalusite crystal by means of capillary forces.