Some Properties of Single Crystals of Potassium Hexatitanate

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[Received May 14, 1983]

六チタン酸カリウム単結晶の二、三の性質

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(1983年5月14日受付)

Key-words : Potassium hexatitanate, Coefficient of linear thermal expansion, Vickers hardness, Tensile strength

Potassium hexatitanate ($\text{K}_2\text{Ti}_6\text{O}_{13}$) shows the highest melting point ($1370^\circ\text{C} \pm 15^\circ\text{C}$) and the best refractory properties among the compounds of potassium titanate, $\text{K}_2\text{O} \cdot n\text{TiO}_2$, where n is 1 to 6. The $\text{K}_2\text{Ti}_6\text{O}_{13}$ fibers are mainly used as a thermal insulator, an automotive brake lining and a filler for various composite materials. Recently, the mechanical and thermal properties of sintered $\text{K}_2\text{Ti}_6\text{O}_{13}$ have been reported to be a good thermal insulator with small thermal conductivity and high bending strength^{1),2)}. However, physical properties of $\text{K}_2\text{Ti}_6\text{O}_{13}$ single crystals have not been determined yet except a tensile strength obtained by Gullledge³⁾.

The authors tried to prepare $\text{K}_2\text{Ti}_6\text{O}_{13}$ single crystals, and the present note is concerned with some physical properties of the single crystals.

The single crystals of $\text{K}_2\text{Ti}_6\text{O}_{13}$ were successfully prepared by the flux evaporation method which was held at 1200°C for 120 h using a K_2MoO_4 flux melt. The single crystals were always grown in an acicular form with colorless, 0.05–0.3 mm in diameter and 5–10 mm in length, elongating along the b -axis.

The coefficient of linear thermal expansion (α_{20-t}) along the elongate direction of $\text{K}_2\text{Ti}_6\text{O}_{13}$

single crystals was determined by following method, DIN 52 328 (April 1967), in the temperature range of 20°C to $t^\circ\text{C}$, and the t was changed from 20°C to 990°C . The temperature dependence of α_{20-t} is exhibited in Fig. 1. The data on the curve 1 represents the average value of α_{20-t} among the different three crystals and the curve 2 is the data

Fig. 1. Temperature dependence of the coefficient of linear thermal expansion for $\text{K}_2\text{Ti}_6\text{O}_{13}$ single crystals.

from a crystal thermally once treated up to 1000°C. The mean value of α_{20-t} on the curve 1 is $8.7 \times 10^{-6}/^\circ\text{C}$ and is $8.8 \times 10^{-6}/^\circ\text{C}$ on the curve 2. These results indicate that the single fibers have very high thermal stability up to at least 1000°C. These values obtained are slightly larger than that of $6.8 \times 10^{-6}/^\circ\text{C}$ on the sintered $\text{K}_2\text{Ti}_6\text{O}_{13}$, which was measured in the temperature range from room temperature to 1000°C. This cause is related to the crystal structure. The crystal structure of $\text{K}_2\text{Ti}_6\text{O}_{13}$ is characterized by a framework of TiO_6 octahedra forming independent parallel channels where the K ions can fit⁴⁾. Therefore, this crystal is expected to show anisotropic thermal expansion. The coefficient of linear thermal expansion along the *b*-axis (or channel), the fiber-axis, seems to be the largest value.

The Vickers hardness (H_V) on the {100} surfaces of $\text{K}_2\text{Ti}_6\text{O}_{13}$ single crystals was measured, and was compared with the H_V of sintered samples. The mean H_V value of single crystals was $616 \pm 30 \text{ kg/mm}^2$ under a load of 50 g, and that of the sintered samples gave $496 \pm 90 \text{ kg/mm}^2$ under a load of 200 g. These values correspond to the Mohs hardness number between 4 and 5, and are suitable as a friction material for the automotive brake lining.

The tensile strength of $\text{K}_2\text{Ti}_6\text{O}_{13}$ single crystals was measured using a microtester which produced by way of trial. The heat treatment of sample was made by the micro-beam of YAG laser. **Figure 2** exhibits the result of the tensile strength at room temperature and 800°C. The maximum value of tensile strength was 192 MPa. This value agreed well with that of a single fiber obtained by Gullledge³⁾. The tensile strength of single crystals shows no difference at room temperature and 800°C, although it is dependent on the diameter. When the diameter exceeds 100 μm , the strength decreases abruptly. It was found that the tensile strength of single

Fig. 2. Temperature dependence of the tensile strength for $\text{K}_2\text{Ti}_6\text{O}_{13}$ single crystals.

crystal at the breakdown was the same value as the bending strength of the sintered $\text{K}_2\text{Ti}_6\text{O}_{13}$ ¹⁾.

The mechanical strength of whisker or single fiber is generally known to be higher than that of the sintered polycrystal such as Al_2O_3 ⁵⁾. It is inferred that no difference of strength between single crystals and polycrystals may be due to the defect of single crystal such as some cracks or voids. Especially, the formation of voids in crystals is associated with the preferential rapid growth along the *b*-axis.

It is concluded that the crystalline $\text{K}_2\text{Ti}_6\text{O}_{13}$ fibers have a potential for good refractory and filler materials with small thermal expansion and large tensile strength and that they may be useful as a good friction material with suitable hardness.

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