# Growth of $Al_2O_3/Y_3Al_5O_{12}$ mixed crystal fiber by high-temperature adaptation of micro-pulling-down method

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## ABSTRACT

### Introduction

It is well known, that there are excellent high-temperature properties of YAG matrix composites reinforced with sapphire phase [1]. Such high-performance materials are of interest to use in advanced aerospace structures, automobiles, high efficiency gas generators and other high-temperature applications. It is well known that especially fiber crystals show an ultra-high strength yielding in pure monocrystalline sapphire fibers at 300 K >1 GPa [2]. This is due to their crystalline perfection and small dimensions, which minimize the occurrence of the defects that are responsible for the low strength of materials in bulk form. Moreover, is has been demonstrated in numerous other fibers, that the tensile strength increases with fiber diameter[3,4]. Therefore, it is a quite interest task to investigate the fiber growth of eutectic composites and compare with single phase filaments and bulk properties.

### Experimental Procedures

The starting materials were 4N purity $Al_2O_3$ , produced by 'High-Purity Chemicals Co.' and $Y_2O_3$ produced by 'Nippon Yttrium Co.' in the molar ratio of 81.3 mol % $Al_2O_3$/ 18.7 mol % $Y_2O_3$. Our adaptation included iridium crucible rated for 1 $cm^3$ of a melt directly coupled with 10 kW power generator, iridium afterheater and proper thermal insulation, Fig.1. The conical crucible bottom had a central capillary opening 0.25-0.35 mm in diameter and 1 mm in length. The end face of the crucible bottom was flat and varied in size within of 0.35-0.80 mm in different growth experiments. Sapphire [001] seed was attached to the holder provided with X-Y manipulator for final alignment with the crucible bottom. Meniscus and growing crystal were observed by CCD camera. Growth process was controlled manually by adjustment power to changes in pulling rate and using as a clue the ratio of meniscus height to fiber diameter. Experimentally the reasonable ratio was found to be 1:8-10.

### Results and Discussion

We successfully got fibers 200μmϕ in diameter (thinnest) shown in Fig. 1. Structure photomicrographs shown in Fig. 1 were obtained from the cross-sections made perpendicular to growth direction by scanning electron microscopy (SEM) and recorded as digital images. By electron microprobe analysis the white phase was proved to be YAG and the dark phase to be $Al_2O_3$.

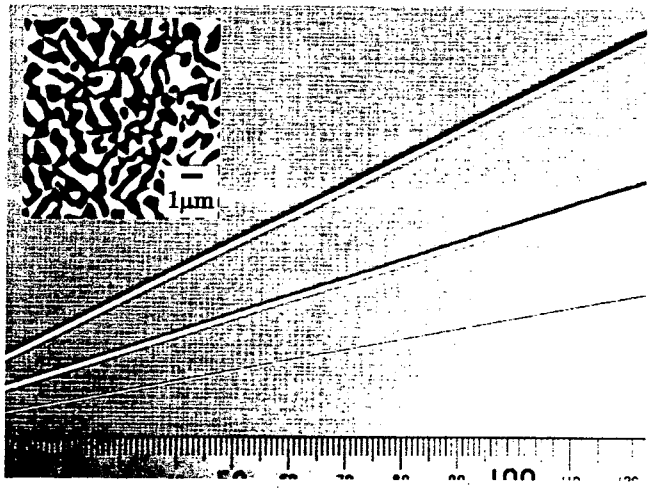


Fig. 1 $Al_2O_3/Y_3Al_5O_{12}$ mixed crystal fiber and its microstructure.

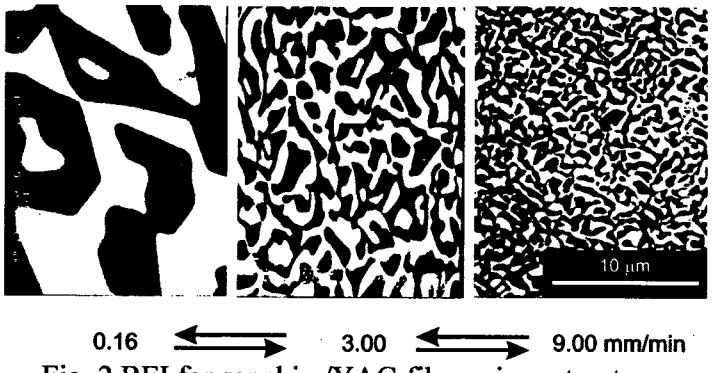


Fig. 2 BEI for sapphire/YAG fiber micro-structures.

## Conclusion and Summary

In summary, the μ-PD method has been successfully adopted for high-temperature processing of oxide materials. Sapphire/YAG fiber 0.20-1.0 mm in diameter and 500 mm in length free of grains, pores and cracks were grown at pulling rates 0.15 - 20.00 mm/min in argon ambient and using 4N purity starting materials. Fine 'Chinese script' lamella dispersion was completed throughout the entire cross-section of grown fibers with excellent reproducibility [Fig. 2]. The interlamellar spacing for script structure agrees with the inverse-square-root dependence on pulling rate according to $\lambda = 10\times v_p^{-1/2}$, where $\lambda$ has dimension of μm and $v_p$ - μm per second [Fig. 3].

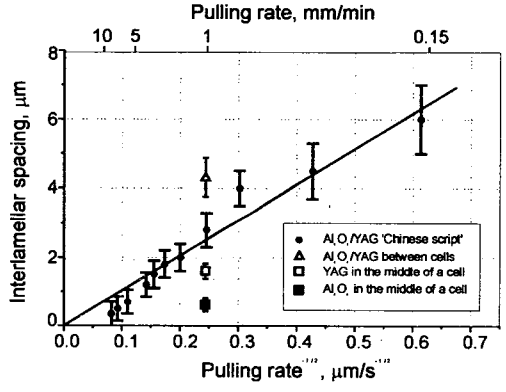


Fig. 3 Interlamellar spacing for sapphire/YAG fiber micro-structures v.s. pulling rate

## References

[1] WAKU et al. 1996 [2] POLLOCK 1972 [3] ALAHVERDI et al. [4] STRÖM-OLSEN et al.