COMPOSITE OXIDE FIBRES

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Abstract
Reinforcing brittle matrices such as ceramics with fibres allows designing composites with quasi-plastic behaviour. A traditional way to achieve the result mentioned is the formation of a "weak" fibre/matrix interface by coating the fibre with an appropriate material. For polycrystalline oxide fibres, a highly anisotropic oxide, calcium hexaaluminate, has been used as a coating material. "Weak" interfaces can also be introduced into a brittle matrix by reinforcing it with a special type of fibres of a composite structure. The present paper discloses one type of such fibres composed of sapphire matrix and calcium hexaaluminate inclusions, which can be located on both the fibre surface and in fibre volume. The developed can be used as a reinforcement for brittle-matrix composites.
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1. Introduction

Fibrous composites provide a possibility to involve brittle materials, including inherently brittle substances, into structures demonstrating non-brittle behaviour. Normally this is a result of crack tip behaviour at the "weak" fibre/matrix interface [1]. A usual way to organise such kind of the interface is to coat the fibre with an appropriate material. For example, in the case of oxide-fibre/oxide-matrix composites, polycrystalline fibres are coated with either monazite or hibonite type of the oxides [2-4]. Polycrystalline oxide fibres are creeping at rather low temperatures [5], single crystalline fibres are normally obtained by a technology of low productivity rate, so they are too expensive to be used in structural materials [5]. The internal crystallisation method (ICM) to produce single crystalline fibres provides the productivity rate much higher than that of the traditional methods gives fibres suitable for the structural materials [5]. Another advantage of the ICM is its relative simplicity, which opens a possibility to speed up developing a variety of the fibres. In the present paper, fabrication, microstructure and mechanical properties, as well as possible applications of composite oxide fibres composed of single crystalline alumina and calcium hexaaluminate (CA6) are discussed.

2. Fabrication, microstructure and room temperature strength of CA6 fibres

Composite oxide fibres have been prepared by using the internal crystallization method (ICM), which is actually crysallisation of an appropriate melt in the channels of an auxiliary matrix [5]. A schematic of the ICM is presented in Fig. 1. After crystallization is completed, molybdenum is dissolved in a mixture of the acid that yields a bundle of fibres, which can contain hundredths and thousands of the fibres. Because of the way to make the molybdenum carcass, a fibre has two flat and two concave surfaces.

The microstructure of a fibre is illustrated by Fig. 2 where actually an example of the fibre made of pure hexaaluminate is shown for clarity. It can be seen that the external flat surface of the fibre is coincided with the basis crystallographic plane of CA6. Also it is obvious that the fibre is not single crystalline and the fibres of such type cannot be sufficiently strong. Hence, composite fibres containing sapphire matrix and CA6 inclusions are wanted.

Composite fibres were crystallized from raw mixtures of calcia and alumina containing 2 – 3 – 4.5 – 6 mass per cent of calcia in alumina. Pulling rate of the oxide/molybdenum blocks in the crystallization process varies from less than 1 mm/min to 800 mm/min. Fig. 3 shows light inclusions of complex calcia-alumina oxide inclusions in basically alumina fibres in cross-sections of the fibres obtained from raw mixture Al_2O_3+6%CaO placed in a matrix. This makes visual impression of the fibres deviated from the cross-section form described above.

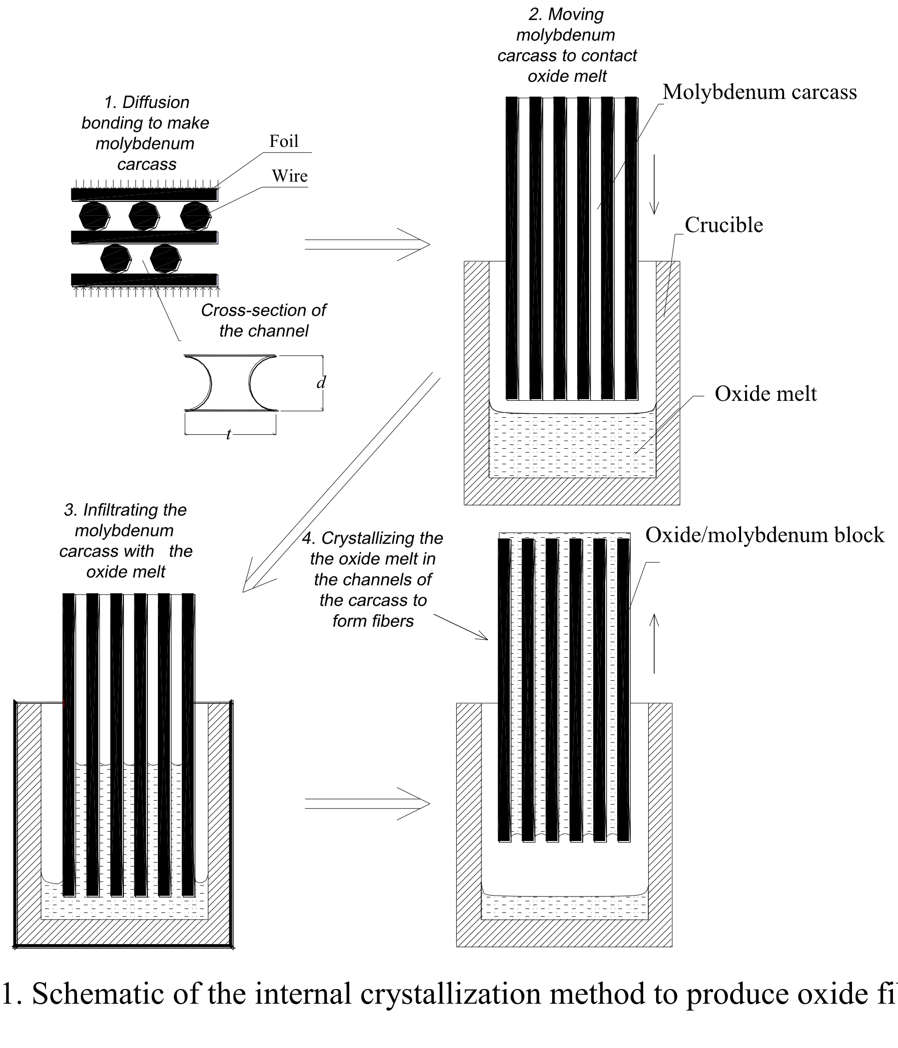


Fig. 1. Schematic of the internal crystallization method to produce oxide fibres.

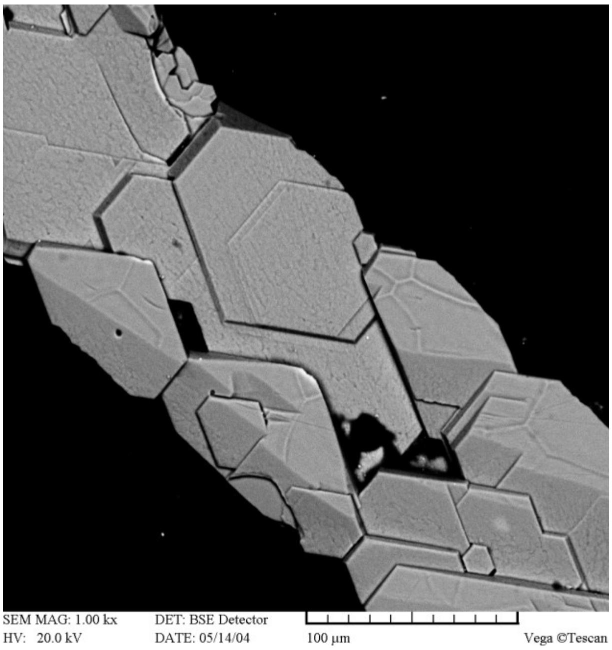


Fig. 2. A flat surface of the fibre made of pure hexaaluminate.

Strength behaviour of the fibres is illustrated in Fig. 4. Note that test technique used to receive the information on strength behavior of the ICM-fibres is based on measuring ultimate strain of the fibres [5]. Hence, to obtain the fibre strength one needs to know a value of the Young's modulus of the material. Since data on elastic properties of hexaaluminate are not known, the data in Fig. 4 can be used to calculate the strength values taking value of the Young's modulus equal 400 GPa to the first approximation.

3. Experimental evidences of crack arrest in brittle matrix composites possible applications of composite oxide fibres

The molybdenum matrix undergone heating up to about 2000^{o}C during the crystallization process is brittle, it reveals no plastic deformation. Corresponding composites reinforced with sapphire fibres are also brittle and their failure surfaces have no traces of fibre pull-out [5]. Fig. 5 shows quasi-plastic behaviour and fibre pull-out, which results in such composite behavior.

Obviously there could be applications of the fibre studied to obtain quasi-plastic behavior of composites with other brittle matrices.

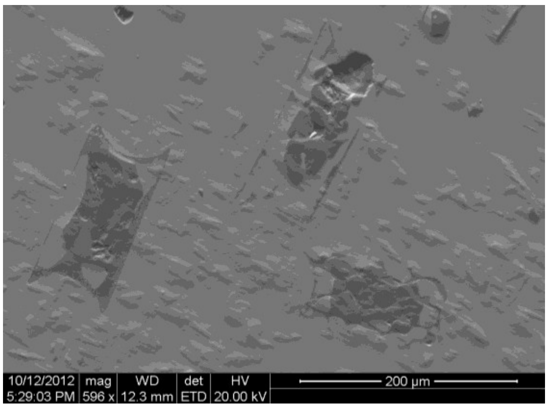
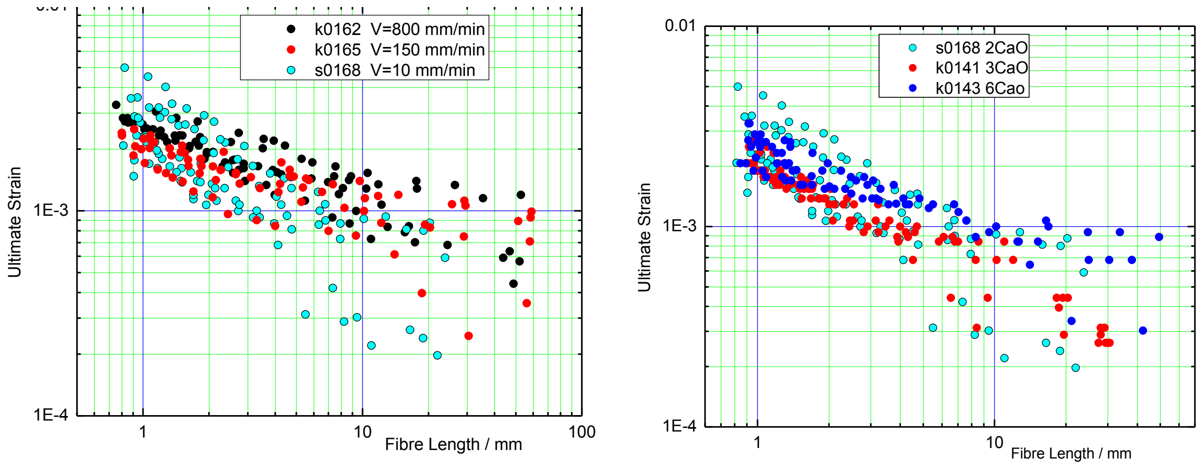
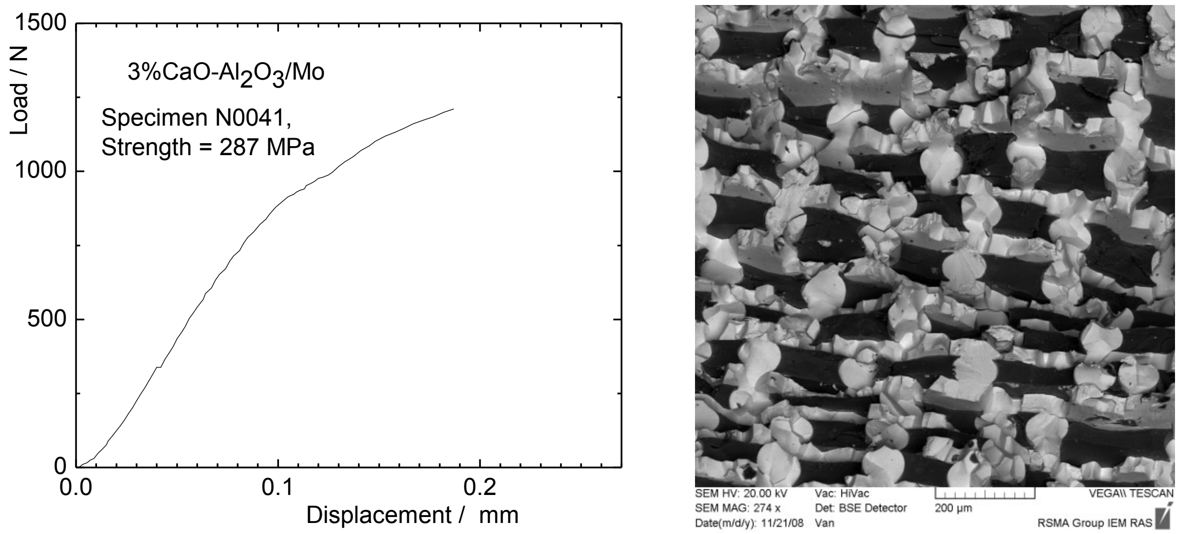


Fig. 3. Cross-sections of the fibres obtained from raw mixture Al_2O_3+6%CaO.



(a) (b)

Fig. 4. Dependencies of the ultimate strain of the fibres obtained from raw mixture Al_2O_3+2%CaO on the pulling rate (a) and those for the fibres obtained from raw mixtures Al_2O_3+xCaO (x = 2, 3, 6%) and pulling rate ~ 5 mm/min (b).



(a) (b)

Fig. 5. Load/displacement curve of a composite with brittle molybdenum matrix under 3-point bending (a); a failure surface of similar specimen with a fibre obtained from raw mixture Al_2O_3+2%CaO at pulling rate of 1 mm/min.

4. Conclusion

Composite oxide fibres with a special type of the "weak" inclusions are obtained by using the internal crystallization method. The usage of them as reinforcement for brittle matrices yields composites with quasi-plastic behavior.

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