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Effect of testing conditions and doping on
superplastic creep of alumina

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In recent years, large tensile and compressive strains have been achieved on many fine grained ceramics materials [1-2]. Their general behaviors (temperature, grain size, stress exponents and strain rate,...) can be characterised as superplastic according to the definition of metallurgists. Recently, we have done an extensive study of fine grained ($1\text{ }\mu\text{m}$) MgO doped alumina by compressive creep tests at $1450\text{ }^{\circ}\text{C}$ [3]. It was unambiguously established that:

- normal grain growth took place concurrently with deformation, leading to continuously decreasing strain rates.
- the constant applied stress does not influence the time exponent in the grain growth kinetic law but enhances the rate constant.
- cavitation occurs at grain triple junctions due to extensive grain boundary sliding.
- some crystallographic texture evolutions have been observed even at low stress levels (10 MPa) which cannot be explained by basal glide.

The behavior of alumina appears very similar to that of metallic systems at the macroscopic level (stress exponents,...) as well as with respect to microstructural evolutions. It may be considered as a model system to study the grain-boundary behaviors which determine the structural evolution during superplastic deformation.

Fig. 1. Strain rate variations during creep tests in compression C and tension T for Mg doped (CMG) and Y co-doped (CMGY) alumina with respectively $0.8\text{ }\mu\text{m}$ and $0.66\text{ }\mu\text{m}$ initial grain sizes.

In this context we present here some preliminary results on direct comparison between compression and tensile behaviors of MgO doped alumina and with two kinds of additional doping elements (Y_2O_3 500 ppm and Ti_2O_3 1 % weight). Tests have been performed in creep conditions under constant stresses. At $1450\text{ }^{\circ}\text{C}$ under 20 MPa elongations to

Fig. 2 Strain rate versus time for compressive C and tensile T tests at $1250\text{ }^{\circ}\text{C}$ on Ti doped alumina (initial grain size $0.7\text{ }\mu\text{m}$).

rupture up to 65 % (0.5 true strain) have been observed on Y_2O_3 doped alumina. In tension, strain rates begin to decrease as in compression, likely due to concurrent grain growth (Fig. 1) and are higher in tension than in compression (factor 1.5 to 2) as soon as the test begins. At $1250\text{ }^{\circ}\text{C}$ for the Ti co-doped alumina the behavior is similar (Fig. 2) and strain rates differ by a factor of 4 between tension and compression but failure occurs after only 30 % elongation. The rupture in tension occurs by catastrophic propagation of macrocracks which result from the coalescence or the linking of small equiaxed cavities. Compression tests on specimens with different equivalent diameter to height ratios (0.37; 1; 1.4) have shown that tension/compression differences cannot be explained by friction effects as proposed by Wang and Raj [4] for glass ceramic materials. The strain rate differences appear all the more significant as they are observed from the very beginning of the tests. On the matter of direct comparisons between tension and compression behaviors, the literature appears rather poor on ceramics as well as on metallic materials.

It is suggested that more systematic experimental investigations would be needed before a clear understanding and subsequent modelling of such differences in behaviors can be arrived at.

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