Optimization of Drying Step to Obtain Large, Transparent Magnesium-Aluminate Spinel Ceramics

J. Petit[1], L. Lallemant[1]

[1]ONERA, Chatillon, France

Abstract

Transparent polycrystalline ceramics are generally recognized as an alternative to polymers, glasses or single crystals in optical applications such as windows, armors, discharge lamps envelopes or jewels. The growing interest for this type of materials is mainly due to their strong thermo-mechanical properties up to high temperature (>1000°C), their intrinsic transparency over the visible-IR range and the low costs of the raw materials. Nevertheless, obtaining high light transmission requires a careful control of chemical composition and microstructure all over the process to avoid light scattering sources such as inclusions or porosity. First, high purity starting powders are required as impurities could induce absorption losses. Then, the green bodies processing should lead to a dense and homogeneous particles packing without large aggregates. Finally, the sintering process has to be optimized to remove the porosity.

Green bodies processing is probably the most critical step as it strongly influences the following sintering step. Among the known techniques, wet shaping processes are particularly interesting because they enable the particles to find an optimum position on their own. Nevertheless, the presence of water molecules leads to drying issues. During the water removal, its concentration gradient (Figure 1) induces internal stresses or even cracks limiting the sample size: laboratory samples are generally less damaged because of their small size (around 20 - 30 mm diameter) but upscaling the samples for industrial applications leads to an increasing cracking probability. The aim of this study is to introduce finite element simulations using COMSOL Multiphysics® software as a useful complementary tool to avoid cracks formation during the drying step of large samples. The Transport of Diluted Species interface and Heat Transfer in Solids interface were coupled to optimize the drying parameters such as temperature, relative humidity and time (Figure 2). The critical point is to well define the boundary conditions (water and heat exchanges) between the sample and the environment. Fitting some control samples, the model was then used on large size samples to find the optimized drying cycle parameters: the water gradient in the sample volume must be as low as possible keeping a drying time as short as possible. Those parameters were, at last, experimentally used to obtain crack free plates in a reasonable time.

Thus, 80 mm diameter 10 mm thickness highly transparent spinel plates were obtained (Figure 3). This method is now used with other compounds (alumina, yttria) to obtain even larger samples.

Figures used in the abstract

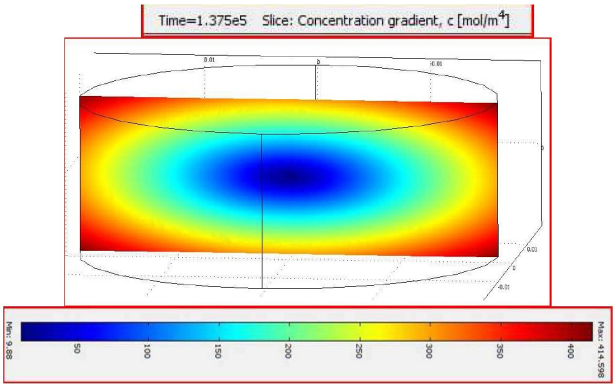

Figure 1: Water concentration gradient in a drying ceramic sample.

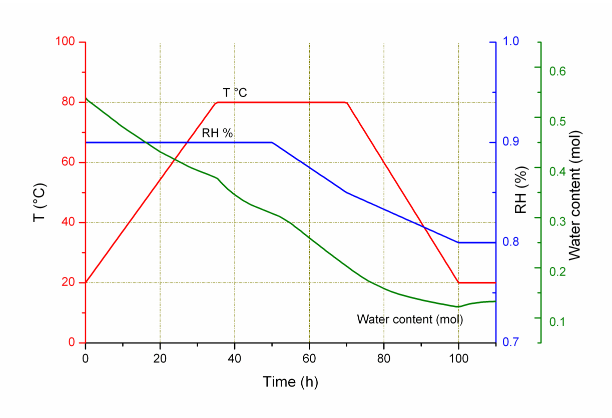

Figure 2: Simulation results of the water content evolution in the sample with respect to the temperature and relative humidity profiles.

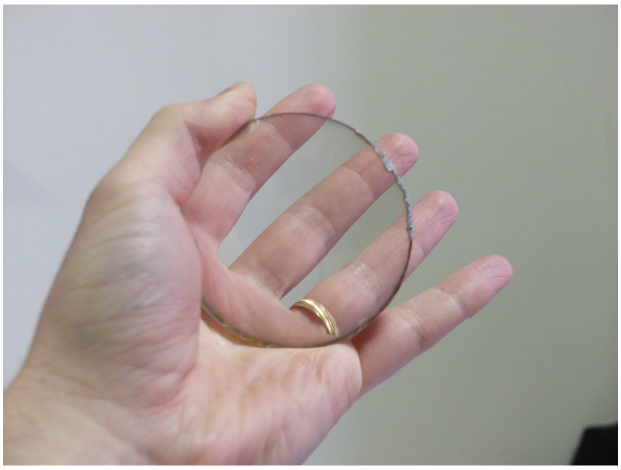

Figure 3: Crack free transparent spinel ceramic (80 mm-diameter ; 10 mm thickness).