Institute of Mineral Engineering
Department of Ceramics and Refractory Materials
Univ.-Prof. Dr. rer. nat. R. Telle

Thermodynamic Materials Modelling

Aerodynamic-Acoustic Levitatior

The Aero-Acoustic Levitator (Physical Property Measurements, Inc., Evanston, Illinois, USA) is a unique instrument for containerless materials processing and synthesis for temperatures up to 3000°C. It enables the contactless and contamination-free in-situ measurement of thermophysical (melting point, viscosity, surface tension, density, thermal expansion) and structural properties of oxide melts. The spherical samples (10 g/cm^3 max.) of -0.25 to 0.35 cm diameter are levitated in a heated (500-600°C) gas stream (air , Ar, N_2, O_2 etc.) and stabilized by acoustic positioning forces generated by 6 piezoelectric transducers (~22 kHz, 165 dB max.) on three orthogonal acoustic axis. The acoustic positioning forces arise from the standing waves, created by the 3 orthogonal pairs of acoustic transducers. The phase differences in each pair of transducers are controlled to adjust the location of nodes in the standing waves that yield the acoustic forces on levitated samples. The feedback positioning control consists of three-axis infra-red laser diode positioning detection with variable gain closed-loop feedback control to acoustic drivers for specimen stabilization. The samples are directly surface heated by two 240 W cw-CO_2 lasers. The experiments are recorded by a high-speed digital video camera (1000 fps at 1632x1200 full sensor resolution) equipped with a long-distance microscope lens system and a fast, high-resolution pyrometer (1000 measurements per second).

Further fields of application of the aerodynamic-acoustic levitation technique are the solidification (undercooling, recalescence, nucleation; nucleus, dendrites and crystal growth; microstructure development etc.), stable and metastable high temperature equilibria (melting points, liquidus surfaces, superheated solids, supersaturated as well as undercooled melts, demixing and miscibility gaps, phase selection, phase transitions etc.) and materials synthesis (ultra-pure materials, glasses, new and unique microstructures, non-equilibrium materials etc.).

Figure three shows, that with this containerless method a undercooling of several hundred degrees below the melting of the materials is possible, which allows the formation of a glass phase even from compositions that under normal conditions show no or little tendency to glass formation like rare earth aluminates.

Further work will concentrate on the determination of surface tension and viscosity of oxide melts. With the aerodynamic acoustic leviator dynamic oscillations can be induced and measured in liquids at very high temperatures and also in the undercooled state. Surface tension and viscosity values can be derived from modelling of experiments based on amplitude modulation of the acoustic forces over the range of frequencies where resonant oscillation can be observed and measuring the resonant frequencies and the decay of oscillation.

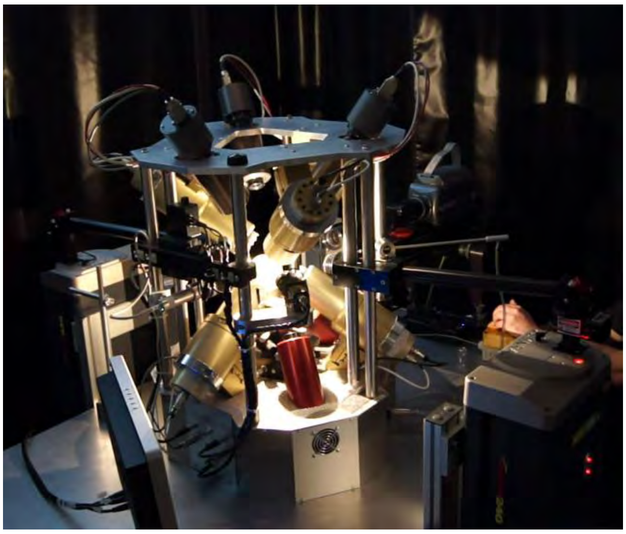

Fig. 1: The Aerodynamic-Acoustic Levitator

Fig. 2: Levitated liquid Al_2O_3 at 2400°C

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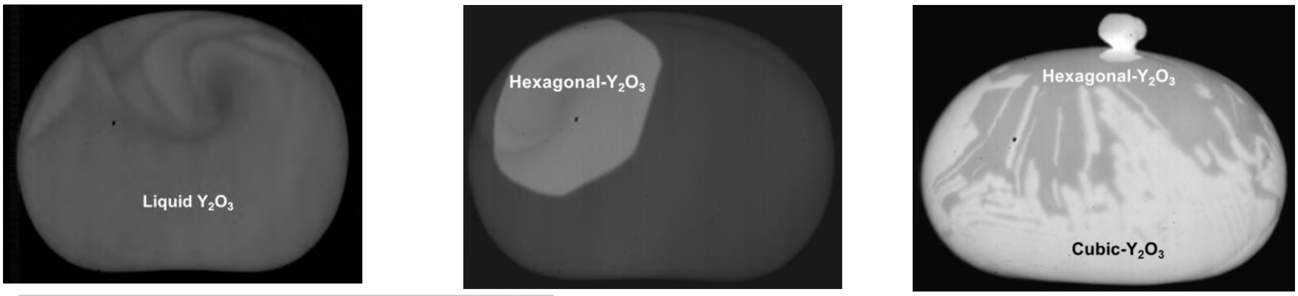

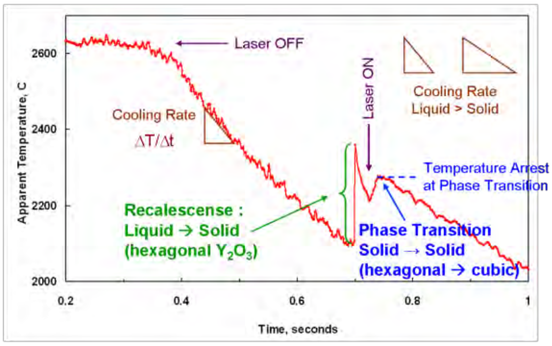

Fig. 3: Undercooling, Crystallization and Phase Transition of Y_2O_3 (above)

The diagram on the left side shows the corresponding cooling curve, documenting the recalescense of the undercooled yttria, followed by the phase transition of hexagonal to cubic Y_2O_3

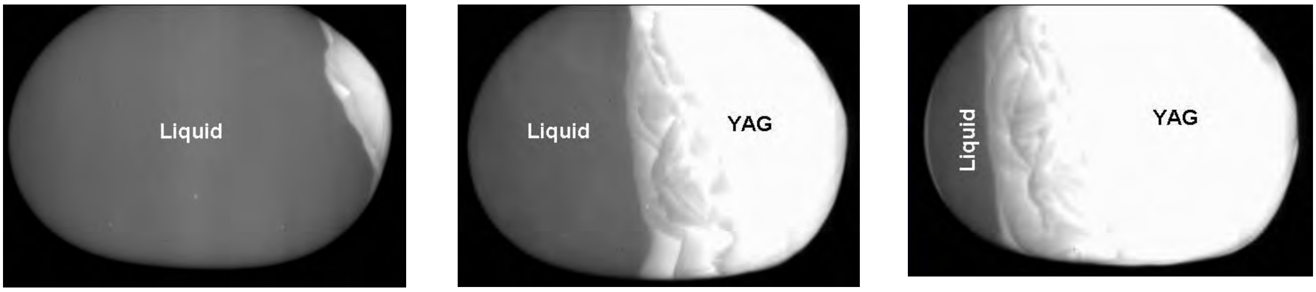

Fig. 4: Crystallization sequence of $Y_3Al_5O_{12}$ (YAG) for a time period of 0.138 seconds

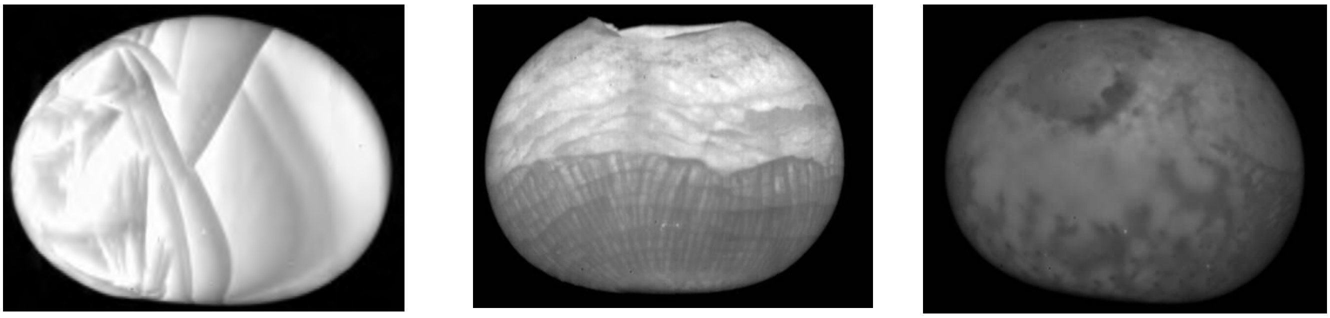

Fig. 5: Three different microstructures resulting from the crystallization of a undercooled YAG composition

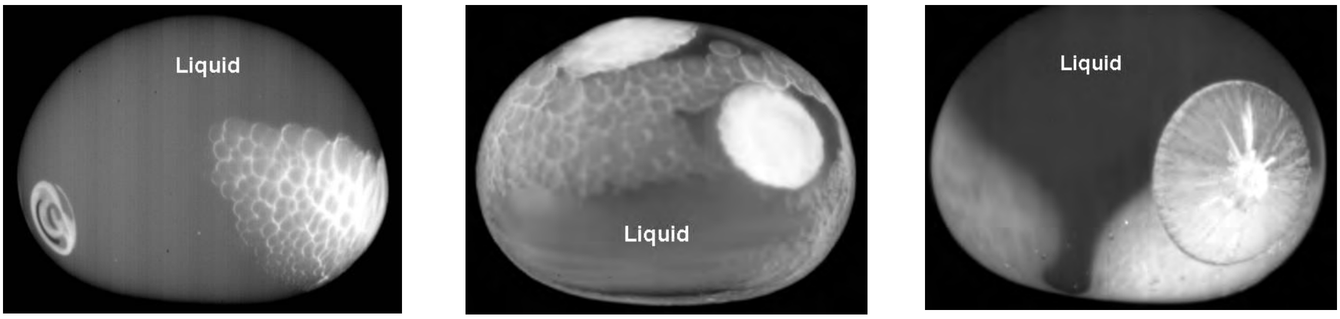

Fig. 6: Undercooling and Crystallization of 50:50 wt-% Al_2O_3:ZrO_2 and of mullite ($Al_6Si_2O_{13}$ / outer right)

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Department of Ceramics and Refractory Materials

Mauerstrasse 5, D-52064 Aachen
phone: +49-(0)241-8094968
fax: +49-(0)241-8092226
www.ghi.rwth-aachen.de

Please contact:

Dr. rer. nat. Arno Kaiser
phone.: +49-(0)241-8094979
fax: +49-(0)241-8092226
e-mail: kaiser@ghi.rwth-aachen.de