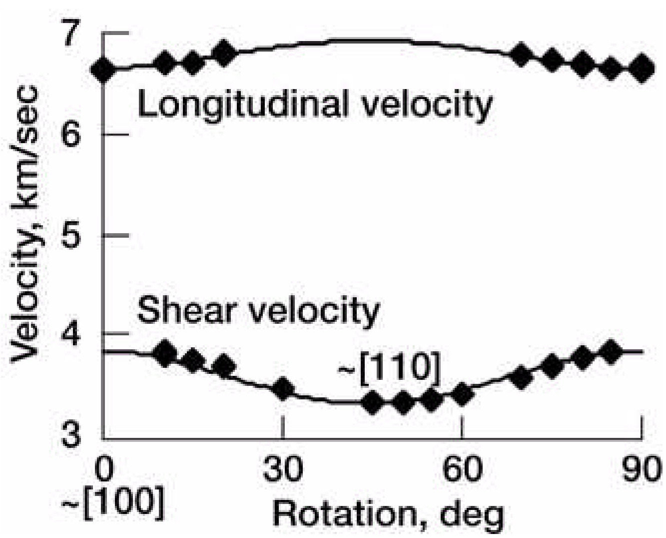
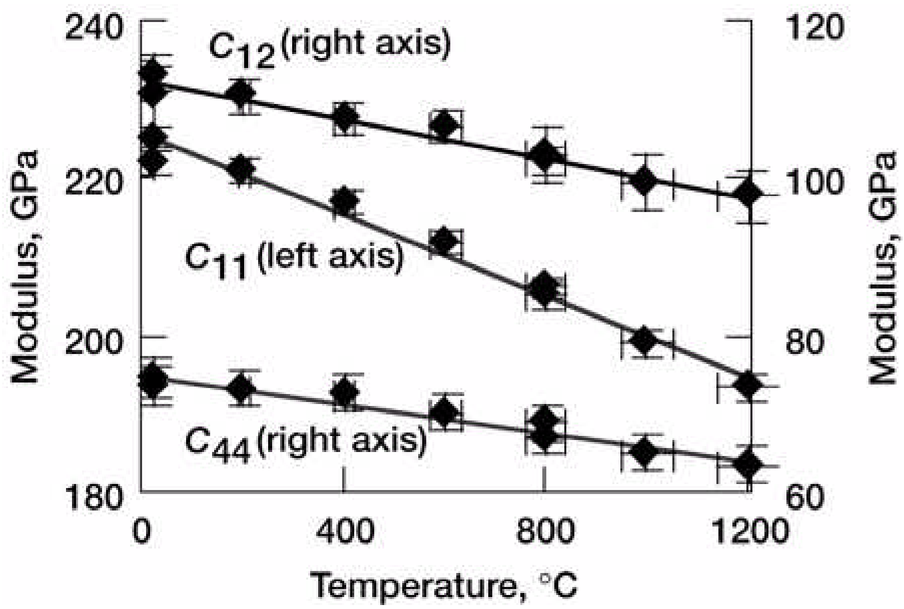
Single-Crystal Elastic Constants of Yttria (Y_2O_3) Measured to High Temperatures

Yttria, or yttrium sesquioxide (Y_2O_3), has been considered for use in nuclear applications and has gained interest relatively recently for use in infrared optics. Single crystals of yttria have been grown successfully at the NASA Glenn Research Center using a laser-heated float zone technique in a fiber and rod. Such samples allow measurement of the single-crystal elastic properties, and these measurements provide useful property data for the design of components using single crystals. They also yield information as to what degree the elastic properties of yttria ceramics are a result of the intrinsic properties of the yttria crystal in comparison to characteristics that may depend on processing, such as microstructure and intergranular phases, which are common in sintered yttria. The single-crystal elastic moduli are valuable for designing such optical components. In particular, the temperature derivatives of elastic moduli allow the dimensional changes due to heating under physical constraints, as well as acoustic excitation, to be determined.

The single-crystal elastic moduli of yttria were measured by Brillouin spectroscopy up to 1200 °C. The room-temperature values obtained were C_{11} = 223.6 + 0.6 GPa, C_{44} = 74.6 + 0.5 GPa, and C_{12} = 112.4 + 1.0 GPa. The resulting bulk and (Voigt-Reuss-Hill) shear moduli were K = 149.5 + 1.0 GPa and G_{VRH} = 66.3 + 0.8 GPa, respectively. Linear least-squares regressions to the variation of bulk and shear moduli with temperature resulted in derivatives of dK/dT = -17 + 2 MPa/°C and dG_{VRH}/dT = -8 + 2 MPa/°C. Elastic anisotropy was found to remain essentially constant over the temperature range studied.





Top: Room-temperature velocities in the {100} plane of yttria. Bottom: Single-crystal elastic moduli at high temperatures. (Copyright James Palko, University of Michigan, Ann Arbor; used with permission.)

Long description

Left: Single-crystal elastic moduli of yttria measured by Brillouin spectroscopy through longitudinal and shear velocity measurements. The measurements have close correspondence to fits from the calculated elastic constants (solid curves). (From ref. 1.)

Right: Temperature dependence of elastic moduli. Linear least squares regressions to the variation of bulk and shear moduli with temperature result in derivatives of $dK/dT = -17\pm 2$ MPa/°C and $dG_{VRH}/dT = -8\pm2$ MPa/°C.

MEASURED AND CALCULATED BULK PROPERTIES OF YTTRIA AT ROOM CONDITIONS

Bulk modulus, *K*, GPa	**Shear modulus, *G*, GPa**	**Young's modulus, *E*, GPa**	**Poisson's ratio,** n
-----------	65.6 ± 0.8	172 ± 2	0.305 ± 0.003
149.5 ± 1.0	66.3 ± 0.8	173 ± 2	0.307 ± 0.003
-----------	67.0 ± 0.8	175 ± 2	0.309 ± 0.003
-----------	56.4	158.3	0.3426
167.7	57.7	155.2	0.3457
-----------	59.0	152.1	0.3488
148.9 ± 3.0	69.2 ± 2.0	179.8 ± 4.8	0.299 ± 0.004
145	67	173	0.30

146.2	69.42	179.8	0.2951

Bibliography

Palko, James W., et al.: Elastic Constants of Yttria (Y_2O_3) Monocrystals to High Temperatures. J. Appl. Physics, vol. 89, issue 12, 2001, pp. 7791-7796.

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