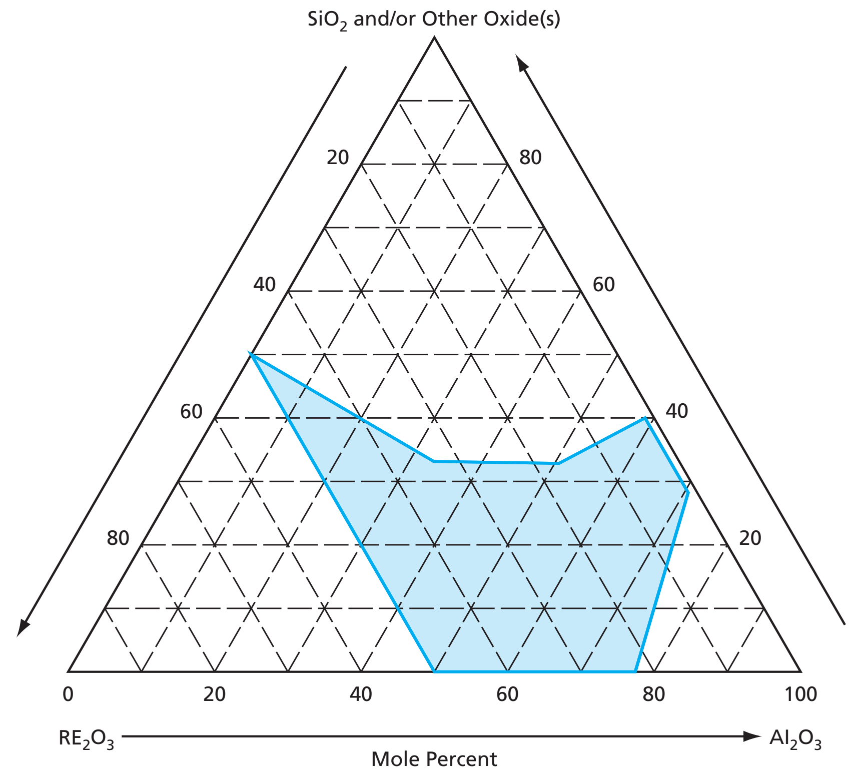
# Single-Phase Rare-Earth Oxide/Aluminum Oxide Glasses

## These glasses are suitable for advanced optical applications.

*Marshall Space Flight Center, Alabama*

Glasses that comprise rare-earth oxides and aluminum oxide plus, optionally, lesser amounts of other oxides, have been invented. The other oxide(s) can include $SiO_2$, $B_2O_3$, $GeO_2$, and/or any of a variety of glass-forming oxides that have been used heretofore in making a variety of common and specialty glasses. The glasses of the invention can be manufactured in bulk single-phase forms to ensure near uniformity in optical and mechanical characteristics, as needed for such devices as optical amplifiers, lasers, and optical waveguides (including optical fibers). These glasses can also be formulated to have high indices of refraction, as needed in some of such devices.

The figure presents a ternary phase diagram showing the range of proportions of the main ingredients of several glasses according to the invention. One rare-earth oxide that is included in every formulation according to the invention is $La_2O_3$, typically in an amount between a few mole percent and a few tens of mole percent. As in the synthesis of other glasses, the oxide ingredients are melted together, then the melt is cooled sufficiently rapidly to a temperature below the melting temperatures of the crystalline phases and below the liquidus temperature of the melt. By "sufficiently rapidly" is meant rapidly enough to ensure solidification into glass before crystallization occurs. The $La_2O_3$ helps to present phase separation during solidification.




The **Colored Area Within the Polygon** represents the range of compositions of single-phase glasses described in the text.

Preferably, during solidification, the melt should not be allowed to come in contact with a solid container because such contact could give rise to heterogeneous nucleation of crystalline material, preventing the formation of glass. For making a very small amount of glass, contact can be prevented by use of a containerless process in which the melt is levitated by a gas stream and heated by a $CO_2$ laser, then cooled by simply turning off the laser. In another containerless process better suited to production of a larger amount of glass, the glass melt is levitated on a thin gas film formed by gas flowing through a porous membrane in a furnace or an electromagnetically heated graphite susceptor.

Alternatively, a relatively large amount of glass can be formed in a conventional float glass process: First, the oxide ingredients are melted together in a crucible. Then the glass melt is cast onto a pool of a suitable molten metal (e.g., tin or gold) that remains molten (and, therefore, not crystalline) at a temperature below the temperature to which the glass melt must be rapidly cooled. Another alternative for making a relatively large amount of glass is to melt the ingredients in a crucible, then cast the melt onto a pre-cooled metal die. Some heterogeneous nucleation of crystals can occur in the glass layer in contact with the metal. However, if the rate of cooling is fast enough (in effect, if the casting is thin enough), then glass is formed before the crystals propagate through the thickness of the casting. Later, any crystals can be removed by polishing the glass surface that was in contact with the metal die.

*This work was done by J. K. Richard Weber, Johan G. Abadie, April D. Hixson, and Paul C. Nordine of Containerless Research, Inc., for* **Marshall Space Flight Center**. *For further information, contact the company at cri_info@containerless.com.*
*MFS-32117-1*