

Conformal ALON[®] Windows

Lee M. Goldman, Sreeram Balasubramanian, Mark Smith, Nagendra Nag, Robyn Foti, Santosh Jha and Suri Sastri; Surmet Corporation, 31 B Street, Burlington, MA 01803

ABSTRACT

Aluminum Oxynitride (ALON[®] Optical Ceramic) combines broadband transparency with excellent mechanical properties. ALON's cubic structure means that it is transparent in its polycrystalline form, allowing it to be manufactured by conventional powder processing techniques. Surmet controls every aspect of the manufacturing process, beginning with synthesis of ALON[®] powder, continuing through forming/heat treatment of blanks, ending with optical fabrication of ALON[®] windows. Surmet has made significant progress in its production capability in recent years. Additional scale up of Surmet's manufacturing capability, for complex geometries, larger sizes and higher quantities, is underway.

The requirements for modern aircraft are driving the need for conformal windows for future sensor systems. However, limitations on optical systems and the ability to produce windows in complex geometries currently limit the geometry of existing windows and window assemblies to faceted assemblies of flat windows. Surmet's ability to produce large curved ALON[®] blanks is an important step in the development of conformal windows for future aircraft applications.

Keywords: conformal windows, transparent armor, sensor windows, domes, optical ceramics, aluminum oxynitride

1. INTRODUCTION

ALON[®] Optical Ceramic is a transparent ceramic material which combines transparency from the UV to the MWIR with excellent mechanical properties. ALON has isotropic optical and mechanical properties by virtue of its cubic crystal structure. The addition of a small amount of nitrogen converts the rhombohedral crystal structure of alumina into the cubic spinel structure of ALON. Consequently, ALON is transparent even in polycrystalline form and thus can be produced by conventional powder processing techniques. This combination of properties and manufacturability make ALON suitable for a range of applications including IR sensor windows, domes and lenses; to transparent armor. Surmet is currently manufacturing and supplying ALON[®] sensor windows in sizes up to 20 in. diameter and armor windows in sizes up to 18 x 35-in. Surmet is working on further increase in size capability.

ALON's manufacturing process begins with the synthesis of the ALON[®] powder from precursor materials. The powder is then formed into a green part, using one of a number of forming techniques which includes: cold isostatic pressing, slip-casting and injection molding. The green part is then heat treated to full optical density, and finally cut, ground and polished into a final component. A schematic of this process is shown in Figure 1.



Figure 1. Schematic of process for producing ALON[®] Optical Ceramic.

Distribution Statement A: Approved for Public Release, Distribution Unlimited

1.1 Forming

The easy and reproducible processibility allows ALON green bodies to be formed by a wide variety of methods in a wide variety of shapes and sizes. ALON green bodies can be formed using any method which works for alumina. The forming method used depends upon the size, geometry and quantity of the component to be produced. Forming methods include:

- Cold isostatic pressing (CIP)
- Die pressing
- Slip casting
- Injection molding

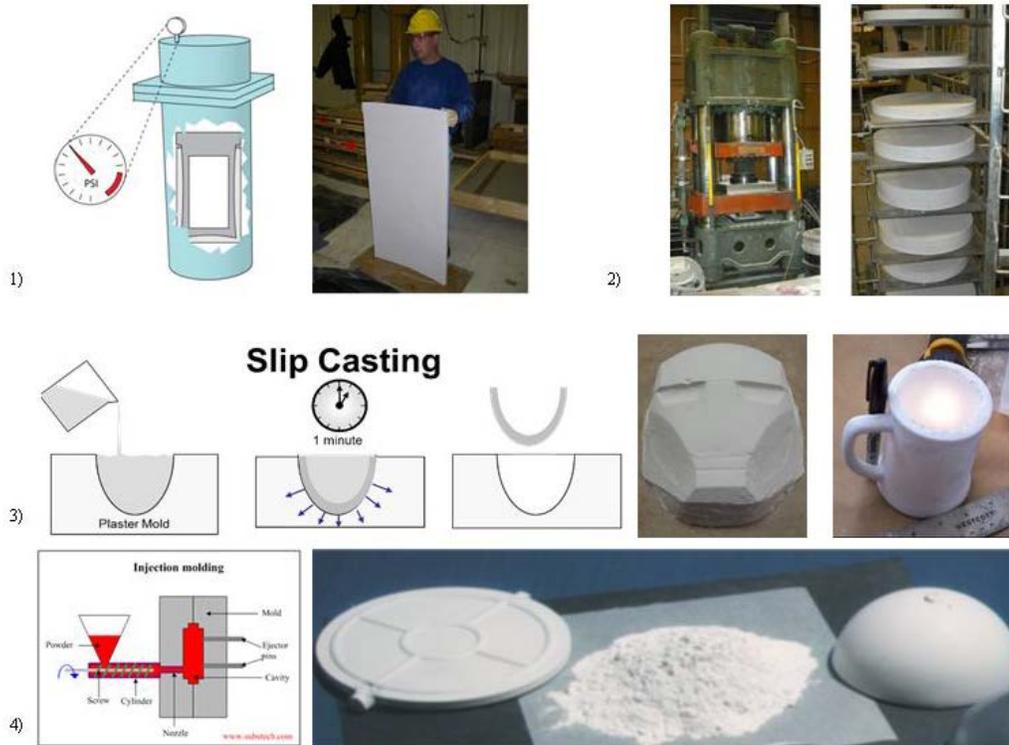


Figure 2. Examples of Forming Techniques Used to Produce ALON Green bodies, and photographs of green bodies formed by those techniques: 1) Cold Isostatic Pressing (CIP), 2) Die Pressing, 3) Slip casting and 4) Injection molding.

The green bodies themselves have the consistency of chalk, which provides them with suitable strength for handling. It also allows the green bodies to be machined to add details or features that are not easily included during forming. It is far easier to machine these parts prior to densification. Green machining is shown in Figure 3.



Figure 3. Green machining.

1.2 Domes with Special Geometries

Distribution Statement A: Approved for Public Release, Distribution Unlimited

The wide variety of forming techniques that can be used to produce ALON[®] green bodies, combined with the ability to green machine those green bodies, allows us to produce dome blanks in a wide variety of shapes and sizes. Examples of such specialized domes are shown in Figures 4 and 5, below.



Figure 4. Tangent Ogive green body and finished domes.



Figure 5. Hyper-hemispherical ALON[®] green bodies and finished dome.

2. CONFORMAL WINDOWS

There is an increasing call for transparent ceramic components with complex curvature. Such components are of interest for both transparent armor and sensor applications. While the optical specifications for these two applications are quite different, the requirements for the manufacture of blanks are quite similar.

For transparent armor in ground vehicles, there are side and rear windows, which generally have cylindrical curvature, and windshields which in general have a more complex curvature. Our initial efforts in this area have focused on the cylindrically curved side windows. Side windows for automotive applications are typically ~20x30-in in size, and have radii of curvature on the order of 80-100-in.

At the time we made our first attempts at making side windows, we were limited in the size of the blanks that we were able to make. Consequently, our first prototypes were tiled from segments <14x20-in in size. Each segment was made with polished, cylindrically curved faces, as is shown in Figure 6.

Distribution Statement A: Approved for Public Release, Distribution Unlimited



Figure 6: Cylindrically curved ALON[®] segments for Side Window for Automotive Application.

These segments were then oriented and shaped to result in a front side driver's door configuration for an automotive application, as is shown in figure 7 below.



Figure 7. Curved ALON[®] Segments arranged to produce a front side driver's door window for an automotive application.

At this time we are able to produce window blanks of sufficient size to produce the entire window from a single blank. Initial curved prototypes are currently in process and will be completed this year. Figure 8 below shows large curved green bodies produced by CIP and Slip Casting.

Distribution Statement A: Approved for Public Release, Distribution Unlimited

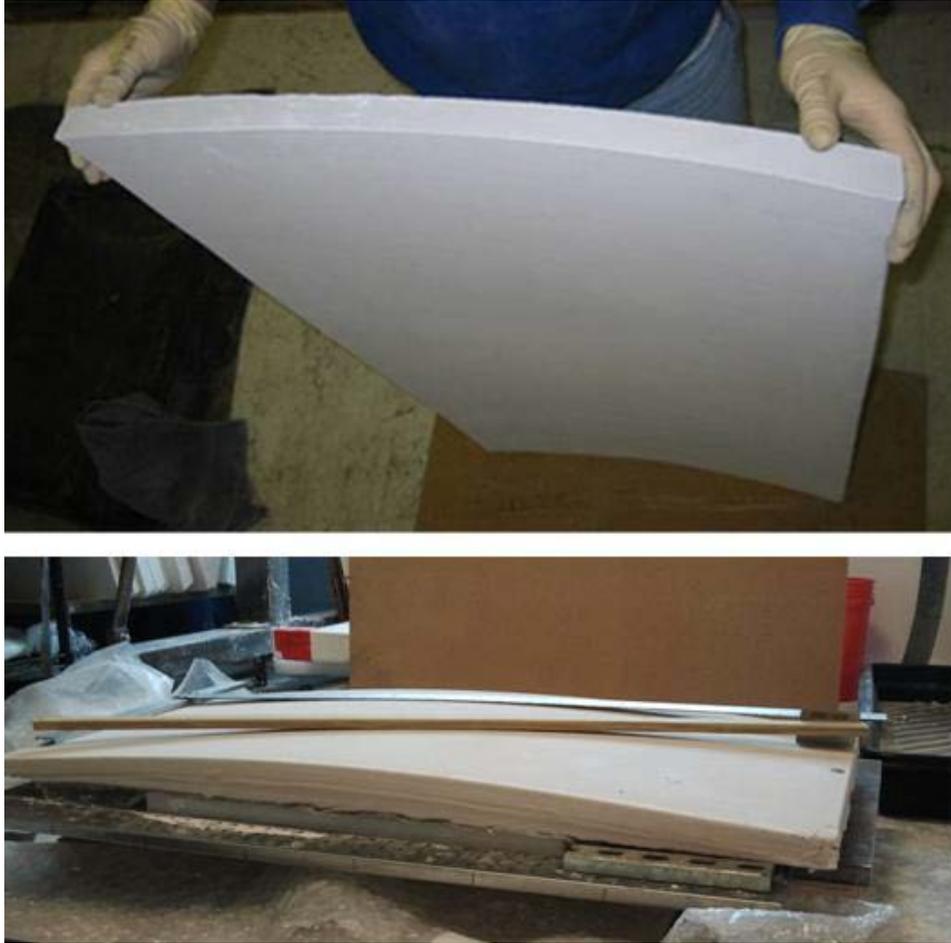


Figure 8. Large cylindrically curved ALON[®] green bodies formed by CIP (top) and Slip Casting (bottom).

For conformal sensor windows there are more options, as the windows must blend in with the geometry of aircraft on which they are mounted. Depending upon the location on the aircraft, the geometry may vary. Geometries for such windows range from the steep curvature found on the leading edge of a wing, to the gentle curvature found on the underside of an airplane, and any combination of curvatures in-between.

Recently, Surmet produced a window blank for such an application. The geometry selected for this project had gentle curvature. Surmet produced this blank for its customer, who will handle the optical fabrication of the blank into the final conformal window. Photographs of this blank are shown in the figure below.

Distribution Statement A: Approved for Public Release, Distribution Unlimited



Figure 9. Photograph of conformal ALON® blank produced for sensor application. Top view (top) and Side View (bottom).

Surmet has developed the ability to quickly and cost-effectively evaluate optical material blanks for inclusions and internal defects prior to fabrication. This allows us to evaluate the quality of the material blank before investing significant amount of time into the final polishing step. Visual inspection of ALON domes and the conformal blank (shown in Figure 9 above) using this method of inspection is shown in Figures 10 and 11, respectively. This technique enables optical inspection of non-polished ALON blanks of complex shapes.



Figure 10. Ground JAGM dome blank (left). Ground JAGM dome blank prepared to allow internal inspection (Right).

Distribution Statement A: Approved for Public Release, Distribution Unlimited



Figure 11. Conformal ALON® Window Blank of Figure 9 was optically inspected for defects.

3. SUMMARY

ALON® Optical Ceramic consists of 95% aluminum oxide with a small amount of nitrogen added to stabilize its cubic structure, making it transparent in its polycrystalline form. This allows ALON to be produced by conventional powder processing techniques. Furthermore, ALON's chemical similarity to alumina (the most widely used technical ceramic in the world) means that any forming method used for alumina ceramic components can also be used to for ALON® green bodies. This means that ALON green bodies can be produced in a wide variety of shapes and sizes, such as those used for conformal dome and window applications.

ALON® domes with tangent ogive and hyper-hemispherical geometries have been produced. Curved ALON® Windows have been produced for transparent armor applications and we are now producing blanks for conformal sensor applications as well.

Surmet has developed the ability to quickly and cost-effectively evaluate optical material blanks for inclusions and internal defects prior to fabrication. This allows us to evaluate the quality of the material blank before investing significant mount of time into the final polishing step.

Distribution Statement A: Approved for Public Release, Distribution Unlimited