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2.C Laser Fusion Target Production: Developments in Drill, Fill, and Plug

Laser fusion target designs frequently require glass microballoons (GMB's) filled with non-fuel diagnostic gases. These "diagnostic" targets are necessary for measuring target temperature, density, hydrodynamic stability, and for calibration of the diagnostic equipment used to measure these parameters during target implosion experiments. Helium and neon are two diagnostic gases that can be permeated through the GMB wall simultaneously with the deuterium-tritium fuel gas. Other diagnostic gases such as argon, krypton, and xenon cannot be easily permeated, since they require excessively high temperatures and exhibit very long permeation times.

The method for making non-fuel diagnostic targets that we have successfully put into production is referred to as the "Drill-Fill-Plug" technique.[1-4] The fabrication procedure involves laser-drilling a hole through the GMB wall, placing a piece of glass-plug-forming material over the hole, filling the GMB with gas in a pressure chamber, then heating the assembly to melt the plug, thus sealing the gas inside the GMB.

The fabrication process begins with selecting GMB's of the proper diameter, wall thickness, and uniformity. These are then fastened to a 4 mm x 25 mm chromium-coated glass slide using sodium chloride crystals as a bonding material. Typically, ten GMB's are put on one glass slide, and the quantity of sodium chloride used must be tailored to the size of the GMB's.

A nominal 1 μm diameter hole is then drilled through the wall of each GMB using a 1.054 μm wavelength yttrium lithium fluoride (YLiF) laser. A typical hole is shown in Fig. 11. This is drilled using the Diagnostic Evaluation Laser (DEL) system with a full-pulse train that consists of approximately 15 pulses of 80-100 ps duration delivered over a period of approximately 1 μs.

Glass-plug material is formed by blowing a bubble of molten Corning #7570 solder glass until it ruptures. A piece of the bubble is selected for

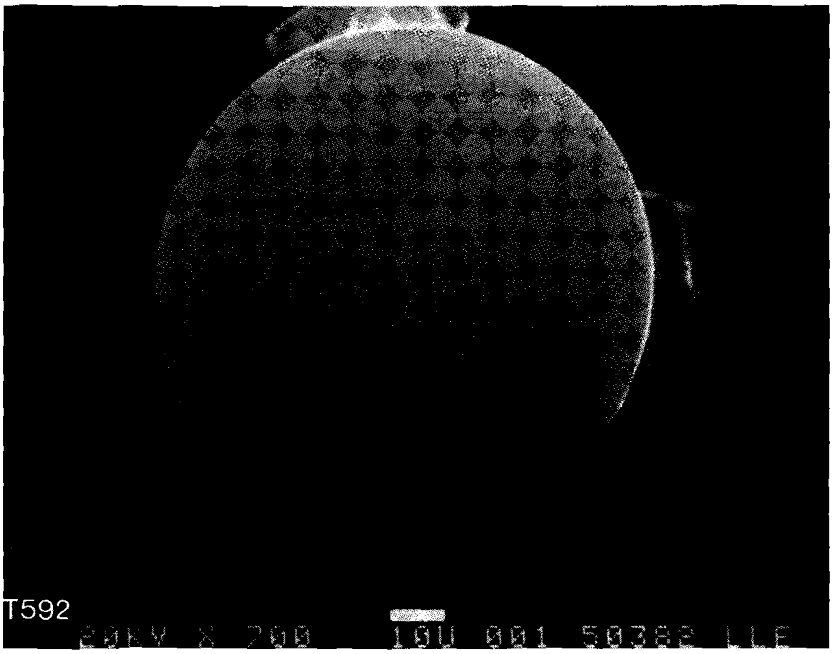


Fig. 11
Scanning electron micrograph of a laser-drilled hole in a glass microballoon which is mounted on sodium chloride crystals.

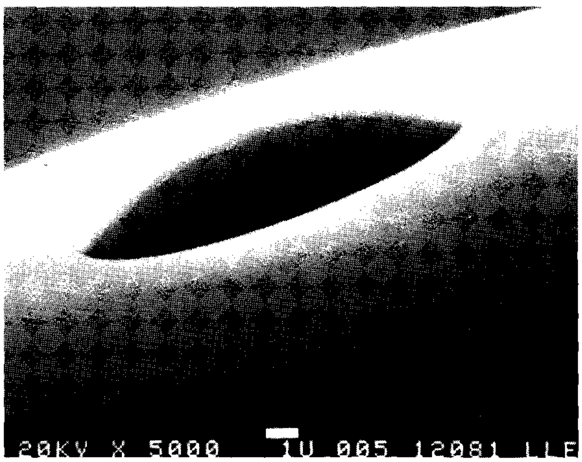
wall thickness, typically 1-2 μm, using an interferometer. The lateral dimensions of the selected piece are always much greater than required to form a plug, so the selected piece must be chopped up into hundreds of fragments. These fragments are then placed on the bottom of a cover slip mounted under a high-power microscope where a single fragment with the desired lateral dimensions, 5-10 μm, is selected. A photograph of these fragments is presented in Fig. 12.

T470

Fig. 12
1280x photomicrograph of solder glass which was blown into a bubble, and then crushed to make thin sheet plugs.

The drilled GMB's are placed on the stage of the microscope where each hole is aligned with a selected glass plug and then raised to bring the hole into contact with the plug. With careful manipulation, the glass plug material sticks to the top of the GMB and remains there through the rest of the process.[4]

The glass slide holding the GMB's is then placed in a small chamber that is evacuated and then backfilled with the proper pressure of specified gases. A Nichrome wire coiled around the GMB's is used to locally heat and melt the glass-plug material over the hole. This heating cycle lasts about 4 minutes. The heater power must be carefully adjusted to the proper level for each gas mixture and pressure. An example of a large plug melted onto a GMB is shown in Fig. 13.



Fused plugs are typically 10 μm in diameter and 1 μm high

- Gas retention - no measurable loss from 10 atm Ar-filled shells after 36 days at STP
- Fill pressure - greater than 60 atm for shells with diameter/wall = 100
- Fuel permeation - hydrogen isotopes can be permeated without plug damage

T440

Fig. 13
Scanning electron micrograph of a large plug, 14 μm in diameter, melted onto the wall of a glass microballoon.

After removal from the plugging chamber, the plugged and filled GMB's can be mounted for additional process steps, such as coating, or sent to be filled with the permeable fuel gas. The fuel permeation is performed at 350°C, which is 100°C less than the softening temperature of the plug glass.

Over 240 GMB's have been successfully filled with non-permeable gases using the Drill-Fill-Plug process. Pressures were from 2 to 60 atm, using argon, neon, and krypton, and with mixtures of neon and argon. Twenty atm of DT have been permeated into GMB's filled and plugged with 2 atm of argon. The overall fabrication process yield has been about 66%. However, when GMB's of a single diameter and wall thickness are used for a series of runs using the same fill specifications, the yield improves with each slide of GMB's and approaches 100%. When the target specifications are changed, the yield drops substantially, but increases as all the parameters are optimized for the new target design.

One important change that is planned for the Drill-Fill-Plug apparatus setup is a complete replumbing of the gas handling tubing. This will reduce the dead volume by a factor of 10 and reduce consumption of the rare diagnostic gases.

ACKNOWLEDGMENTS

The author wishes to thank Alain Coudeville, Centre d'Etudes de Limeil, for suggesting the plug glass bubble-blowing technique and S. Butler, Rochester Institute of Technology, for the plugging chamber development and solder glass selection. We also thank J. Dunsmuir of Exxon Research & Development for personally teaching us the plug placement technique.

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