Section 3
OTHER DEVELOPMENTS

3.A Capillary Gas Filling of Laser Fusion Targets

Introduction

Non-fuel gases are sometimes specified in inertial fusion (IF) targets to aid the diagnosing of the temperature, density, fusion yield and hydrodynamic stability achieved during driver-target interaction experiments and to calibrate various diagnostic instruments. For diagnostic gases other than helium and neon, the usual fuel gas permeation process into the glass microballoon (GMB) target fuel core is not a workable fill procedure because of the small permeation coefficient of glass. Various non-permeation techniques have been developed to load diagnostic gases into IF targets including adding gases by the drill-fill-plug technique,[1-4] adding gases during the GMB fabrication step (drop oven filling),[5,6] or by using some type of gas filling capillary.[7-9] A new fabrication technique has been developed to add diagnostic gases to IF targets by using a gas fill capillary. This technique is more general than those previously used and permits the addition to IF targets of arbitrary gases or gas mixtures over a wide density range.

Fabrication Technique

The production steps of the new technique for fabricating the capillary gas fill IF targets include: (1) attaching a GMB to a hollow glass mounting stalk, (2) laser drilling a hole through the GMB at the stalk location, (3) depositing any additional required target layers, (4) filling the target with the specified gas mixture, and (5) sealing closed the fill capillary to trap the gas. The gas fill capillary, equivalent in dimensions to the usual target mounting stalk, supports the target during the driver irradiation.

The mounting stalk is made from 1.5 mm diameter glass tubing that is drawn to a fine taper using a micropipet puller and that is then ground flat by ultrasonic agitation in water solution while held in contact with an alumina abrasive wafer. Typical dimensions of the drawn and ground tip of the stalk used for mounting a 250 μm diameter GMB are 14 μm outer diameter and 7 μm inner diameter.

The mounting stalk tip is wetted with adhesive and then cleared of any adhesive that may be drawn up into the hollow capillary by applying positive air pressure to the opposite end of the stalk. Fast setting epoxy, RTV silastic, and ultraviolet curing adhesive have been used to attach the GMB to the stalk. The low viscosity and long working time of the UV curing adhesive (Norland Optical Adhesive #60 UV) made it the easiest to use for this application.[10] Equally important, this material has superior adhesion and/or tensile strength properties as evidenced by surviving a higher gas fill failure pressure than did the other types of adhesives tested.

Drilling a hole through the GMB with a short-pulse length 1.05 μm wavelength laser at the location of the attached stalk is the next fabrication step.[11] Using the reverse drilling procedure the laser is focussed through the transparent GMB onto the position where the stalk is mounted.[12] Alignment is facilitated by having a CW helium neon laser coaxial with the drilling laser and by forming an aiming point on the interior surface of the GMB at the correct location. This is achieved by directing white light along the target stalk which serves as an optical waveguide to illuminate the location to drill the hole.

A photomicrograph of a mounted and drilled GMB is shown in Fig. 9. The GMB is 250 μm in diameter with a 1 μm thick wall. The mounting

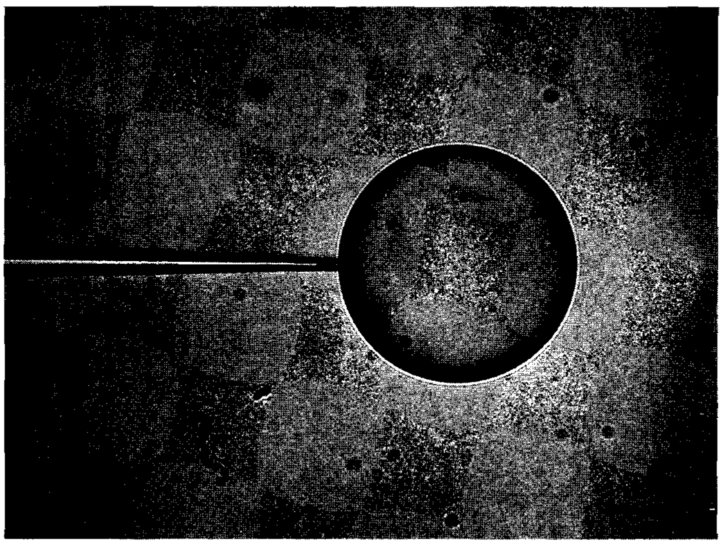

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Fig. 9
Photomicrograph of capillary stalk mounted glass microballoon (GMB). The 250 μm diameter has a 2.5 μm diameter hole drilled through its wall at the stalk position.

stalk diameter at the GMB surface is 10.5 μm. Figure 10 is a scanning electron micrograph of the drilled hole as viewed from the GMB interior. As shown in Fig. 10, the hole is approximately 2.5 μm in diameter at the interior surface of the GMB and is tapered. The sub-micrometer high ridge encircling the hole is formed during the laser drilling operation. At this step in the fabrication process, other materials can be deposited onto the stalk mounted GMB to form pusher and ablation layers, or hemispherical shells can be assembled over the stalk mounted GMB to form a colliding shell target.[13]

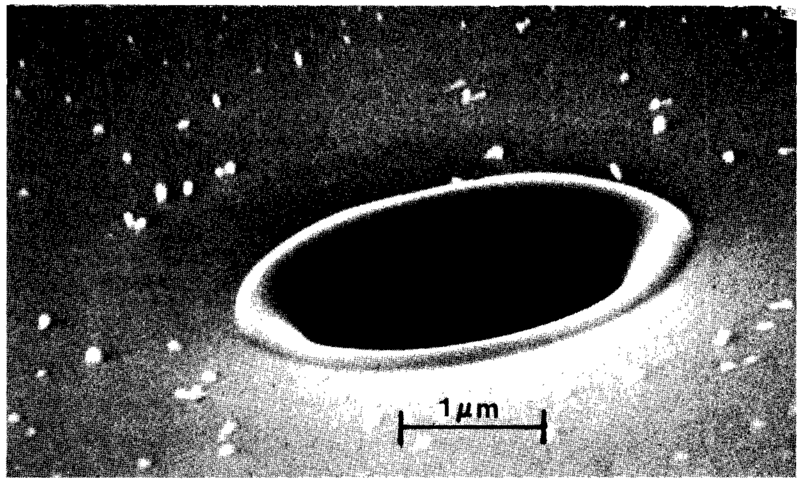

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Fig. 10
Scanning electron micrograph of the 2.5 µm diameter laser drilled hole through the GMB as viewed from the GMB interior. The interior diameter of the capillary stalk at the attachment point is approximately 5 µm.

Adding a single gas or a gas mixture to the target through the capillary mounting stalk is the next fabrication step. Due to the limited conductance of the fill capillary and laser drilled hole in the GMB, no attempt is made to evacuate the target prior to filling. Rather, the target is dilution flushed to reduce gas impurities. The target is filled to about 20 atm pressure with the desired gas, held for a few minutes to allow equilibration, rapidly bled down to a pressure just above atmospheric, and then this cycle is repeated five additional times. This dilution flushing process reduces gas impurities in the target to much less than a fraction of a percent.

After the last flush cycle, the target is filled to the desired pressure and the fill capillary is closed and sealed. A steel ball, coated with UV adhesive and loaded into the glass tubing before the start of the flushing cycle, is moved up to the tapered position in the tube with an external magnet and irradiated with UV light to set the adhesive. Figure 11, a photomicrograph of the steel ball sealed in the glass stalk, shows the dark band of the UV adhesive contact circle. Helium leak tests of this type seal show leak rates less than 1.4×10^{-9} STDcc/s. The gas reservoir volume of the stalk connected to the target is determined by the steel ball diameter and the taper of the glass mounting stalk. The calculated reservoir volume in the fill capillary shown in Fig. 11 is 8.2×10^{-6} cm^3, approximately 8.5 times the volume of the mounted GMB. This fabrication technique permits the addition of most gases or gas mixtures in IF targets up to a pressure of 22 atm, a value determined by the strength of the GMB-capillary fill stalk adhesive material.

Summary

A general fabrication technique for adding diagnostic gases to IF targets has been described. This technique offers distinct advantages to target fabricators. By keeping the reservoir volume in the fill capillary small, the technique can be used with tritiated gas mixtures. In addition, the capillary gas filling fabrication technique has been used to construct a target which serves as a gas fill calibration standard for interferometric characterization.[14]


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Fig. 11
Photomicrograph of capillary gas filled and sealed GMB. The adhesive contact circle on the 250 μm diameter steel sealing ball is evident.

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