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Fabrication of capsules with angle-dependent gold shims for hohlraum drive symmetry correction

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Abstract

In the heavy ion drive hybrid target design for fusion energy, the hohlraum drive suffers from low mode, in particular, P4, asymmetry. Recent target designs have shown that this asymmetry can be removed by shimming the capsule with a high Z material. The shim varies in thickness as a function of the polar angle precisely to correct the asymmetry precisely. In this paper, we report on the first attempt at fabrication of such targets. These targets are typically ~4.7 mm in diameter and 20–30 μm in wall thickness, with a gold coating as the shim, approximately a few tenths of micrometers in thickness. These targets were made for experiments at Sandia National Laboratory's (SNL) double-ended *Z*-pinch experiments, which closely mimic heavy ion drive. We discuss fabrication and characterization issues involved in making these targets.

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Keywords: Fusion; Heavy ions; Shims; Coatings; *Z*-pinch

1. Introduction

The heavy ion hybrid target [1] is attractive for a heavy ion fusion power plant because it allows a large beam focal spot (hohlraum radius ~5 mm). Since focusing the beam to a small spot is difficult, this may reduce the cost of the accelerator and, ultimately, the cost of electricity from a heavy ion fusion power plant. However, the large focal spot does introduce new challenges in achieving symmetry in the target. In the National Ignition Facility (NIF) point design target and the heavy ion distributed radiator target [2], symmetry is achieved by beam placement. In the hybrid target, symmetry is achieved by using shields inside the hohlraum. The beam energy is deposited behind a

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shine shield and radiation flows around the shine shield onto the capsule. This results in an asymmetry because the capsule "sees" a bright source around the shine shield—especially early in time when the hohlraum walls are cold. This P4 asymmetry can be removed using a shim [3]. The shim is a thin layer of material, placed on or near the capsule, to remove a small amount of excess radiation. The shim is placed close to the capsule to minimize the asymmetry and the amount of energy we need to remove. However, putting the shim close to the capsule means that the shim is only effective during the early parts of the pulse. Later in time, the shim layer heats up (losing its opacity) and is pushed away from the capsule by the ablator. While our original motivation for using shims was the heavy ion hybrid target, this symmetry technique should be applicable to any indirect drive targets (laser, heavy ion, or Z-pinch driven). In particular, we have tested this concept on Sandia National Laboratory's (SNL) double-ended Z-pinch (SNL-Z) experiments. The double-ended pinch drive suffers from both a P2 and a P4 asymmetry and therefore the shim is more complicated and contains components to compensate for both types of asymmetry.

In this paper, we discuss fabrication and characterization of targets made for recent experiments at SNL-Z to verify the utility of the shim concept. The shim material was chosen to be gold, which can be deposited by standard physical vapor deposition techniques. This shim layer was deposited on ~4.7 mm diameter, 20–30 μm thick germanium doped CH (Ge-CH) shells (2 at% Ge) which had been used at SNL-Z previously to determine the asymmetry of the drive [4]. In this way, the effect of the shim could be determined directly by comparison with unshimmed Ge-CH targets. The desired shim profile as a function of polar angle is given by

$$f(\theta) = 0.3 + 0.33 * \left[1 - \frac{P4(\theta) + 2 * P2(\theta)}{3}\right].$$

This profile is shown in Fig. 1 along with its projection (for a 4.7 mm diameter shell) on a plane going through the poles. The projection is shown, as it is important in the following discussions on production and characterization of the shim layer.

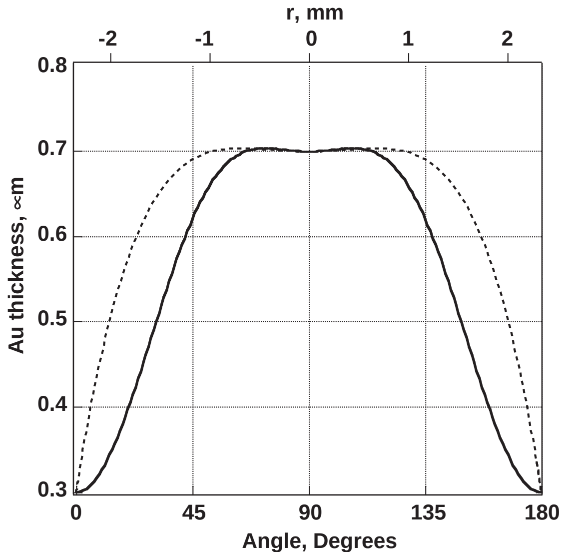

Fig. 1. Calculated shim profile (solid line—bottom axis) to zero out the P2 + P4 asymmetry of the SNL-Z double-ended pinch hohlraum drive. The projection (dashed line—top axis) of this profile on a plane containing the poles is also shown for future reference.

The shim thickness is azimuthally symmetric. This shim profile was determined based on the measured P2 and P4 asymmetries of the double-ended SNL-Z pinch hohlraum drive.

2. Experimental

The Ge-CH shell was made using the depolymerizable mandrel technique, which is currently used for fabrication of the majority of ca psules used in ICF experiments [5]. The details of this process are given in Ref. [5]. Here we briefly mention the main features. A depolymerizable (removable) mandrel fabricated by microencapsulation [6] was coated with Ge-doped CH using Glow Discharge Polymer (GDP) deposition process [7]. The coating process allows achieving the desired wall thickness and doping. The composite was heated to remove the mandrel leaving the thermally stable Ge-CH GDP coating as the final shell. The dopant concentration was determined using micro-X-ray fluorescence and the shell dimensions were measured using interferometry. Wall thickness uniformity, which is especially