GA–A24455

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This is a preprint of a paper presented at the 15th Target Fabrication Specialists Meeting, Gleneden Beach, Oregon, June 1–5, 2003 and to be published in *Fusion Science and Technology.*

Work supported by
the U.S. Department of Energy
under Contract Nos. DE-AC03-01SF22260
and W-7405-ENG-48

GENERAL ATOMICS PROJECT 30095
SEPTEMBER 2003

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The General Atomics Target Fabrication team was tasked in FY03, under its ICF Target Support contract, to make a new type of double-shell target. Its specifications called for the outer shell to have an inner lining of PVA (poly(vinyl alcohol)) that would keep the xenon gas fill from occupying the target wall. The inner shell consisted of a glass shell coated with 2000Å of silver and filled with 9 atm of deuterium. Furthermore, the delivery deadline was less than seven weeks away. This paper describes the fielding of this double-shell target, made possible through the combined efforts of Lawrence Livermore National Laboratory and General Atomics target fabrication specialists.

I. TARGET DESIGN

Figure 1 depicts the double-shell target we were tasked to build. The outer CH shell is 1000 μm in diameter, 12 μm thick and lined on the inside with ~1 μm of PVA. The inner shell is glass, 200 μm in diameter, 2 μm thick, filled with 9 atm of deuterium and coated with 2000Å of silver. The outer shell has a ~250 μm opening to permit insertion of the inner shell, mounted on a 25 μm tungsten wire. The mounting wire in turn protrudes through a 50 μm hole in a beryllium disk, 250 μm in diameter and 50 μm thick, that seals the opening to the outer shell allowing it to hold 1.5 atm of xenon.

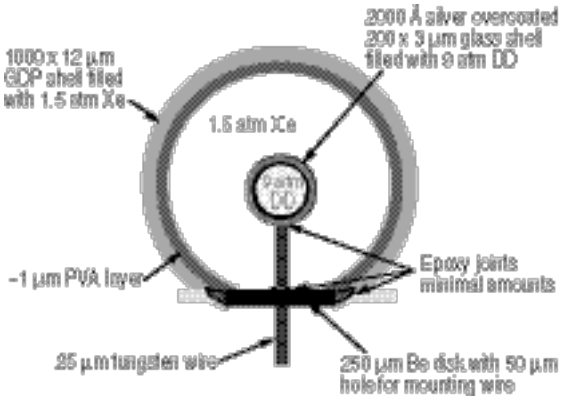

Fig. 1. Double-shell target containing an inner lining of PVA.

II. OUTER-SHELL FABRICATION

The outer-shell fabrication plan we devised consisted of the following steps:

1. Coat PAMS (Poly Alpha Methyl Styrene) shells with PVA using drop tower technology.
2. Over-coat the PVA with 12 μm of GDP (Glow Discharge Polymer).
3. Micromachine a 250 μm hole in the GDP/ PVA/ PAMS shell.
4. Dissolve away the PAMS mandrel with toluene leaving behind a GDP shell lined with PVA on the inside surface.

The outer-shell fabrication process began with the selection from our inventory of a batch of PAMS shells, one millimeter in diameter, made using microencapsulation technology.

We found we had to modified the standard PVA drop tower technique (used to coat 500 μm shells) because the 1 mm shells were still wet when they reached the collection plate at the bottom of the drop tower. We employed two fixes to completely dry the shells as they fell through the five meter tall tower. First, we turned the tower temperature up to the maximum (145°C), that did not result in the PVA solution "boiling" and forming blisters on the shell. Secondly, we diluted the PVA in the water solution down to 6% from the normal ~10% and added 10% isopropanol to speed up evaporation. These

two modifications of the standard drop tower technique enabled us to coat the PAMS shells with ~2 μm of PVA.

We next used bounce pan coating technology to apply the 12 μm thick layer of GDP to the PVA-coated PAMS shells. That operation went routinely.

Micromachining of the hole in the outer shell was done with multi-shell production in mind. As many as five shells at a time were affixed to a glass coverslip using water-soluble pancake syrup "cement," immediately available and shown to work on its first trial.

The coverslip was held by suction to a fixture on a lathe (Fig. 2). Each shell in turn was centered on the axis of rotation and machined by a diamond tool bit that was brought in contact with the spinning shell, cutting a hole of the desired dimensions

We immersed the coverslip holding the now "open" shells in toluene to dissolve away the PAMS mandrel. The air bubble inside the 1 mm shells prevented toluene from entering the hole. To alleviate this problem, we inserted a fine hypodermic needle into the shell through the opening and used it to admit fresh toluene solution into the shell and to remove the dissolved PAMS. We found that the dissolution process was extremely slow, likely due to the restricted fluid exchange through the small hole in the shell. Using the needle, we flushed the shell repeatedly with toluene, until the shell was PAMS-free, typically within 15 min.

The shells now had to be freed from the coverslip by removing the water-soluble "cement" without damaging the PVA layer inside the shell. This had to be accomplished without the water coming in contact with the inside of the shell that would cause the PVA to swell and/or dissolve. We took advantage of the immiscibility and density mismatch of water and toluene. The hypodermic needle was used to place a droplet of water at the bottom of the toluene filled petri dish containing the coverslip. As the density of water was greater than that of toluene, we were able to place the water droplet around the base of the shell where it could dissolve the cement. We used a vacuum pickup tool to remove the water from around the base of the shell and then to remove the shell from the toluene for air drying. Figure 3 depicts the process we developed to remove the PAMS from the GDP/PVA outer-shell.

III. INNER-SHELL FABRICATION

The fabrication of the inner shell required less development than that of the outer-shell. We used interferometric microscopy to culled drop tower glass shells having the desired dimensions from our inventory. We were careful to select a batch of shells that had good gas retention characteristics because of our concern that the shells might become hot during the silver deposition process and as a result lose their deuterium gas fill. We permeation filled the glass shells with deuterium and sent them to Lawrence Livermore National Laboratory (LLNL) for silver coating.

LLNL target fabricators found that the small 200 μm shells were prone to being lost in their bounce pan silver-deposition system. To assuage this problem, they immobilized the shells on a tacky polymeric substrate and silver-coated them on one side then manually turned them over and coated the other side. Upon their return to General Atomics, we determined the fill pressure of one of the silver-coated shells by breaking it in a chamber of known volume, measuring the resultant pressure rise and calculating the shell pressure, knowing the shell's diameter. That measurement came in close to 9 atm, indicating that there was no significant deuterium loss due to heating during the silver deposition.

IV. BERYLLIUM DISK FABRICATION

The fabrication of the beryllium disk "plug" was also done at LLNL. A 50 μm thick beryllium flat, several

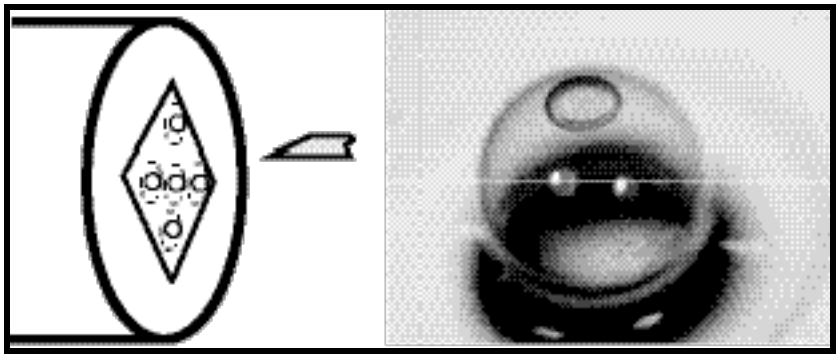

Fig. 2. GDP/PVA/PAMS shells were held in place with hardened Aunt Jemima syrup on a coverslip (held in turn by vacuum on a lathe). After centering one shell at a time on the lathe's axis of rotation, a diamond tipped machining tool cut a 250 μm hole in each shell.

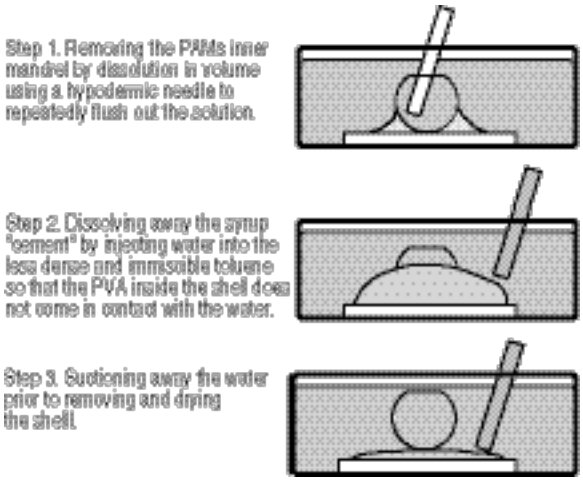

Fig. 3. Process used for removing the PAMS mandrel from the final GDP/PVA shell and freeing it from the glass coverslip.

millimeters square, was laser machined to produce the disks. Figure 4 shows the beryllium flat with disks still attached.

V. TARGET ASSEMBLY

The target assembly was very intricate. A drawn glass capillary tube served as the double-shell mounting post to which we epoxied a millimeter long, 30 μm thick, tungsten wire. The wire was threaded through the hole in the beryllium disk and epoxy was applied such that the appropriate length of wire would support the inner shell within the outer shell. Next, the inner-shell was epoxied to the end of the tungsten wire protruding from the beryllium disk. Finally, the inner-shell was inserted into the outer-shell and the beryllium disk was epoxied to the rim (Fig. 5). Optical microscopy using orthogonal views was used to position the components during assembly and to measure the concentricity of the inner shell relative to the outer shell. For all delivered double-shell targets, the center of the inner shell was located within 30 μm of the center of the outer shell that, acceptable to the experimentalist.

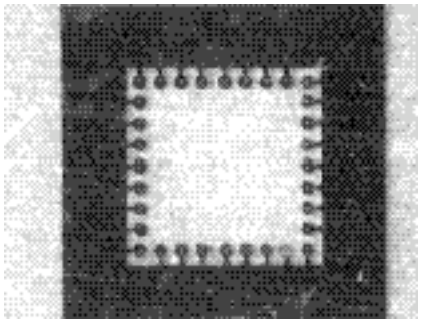

Fig. 4. LLNL fabricated numerous 250 μm disks, each containing a 50 μm hole, by laser machining the 50 μm thick beryllium flat pictured above.

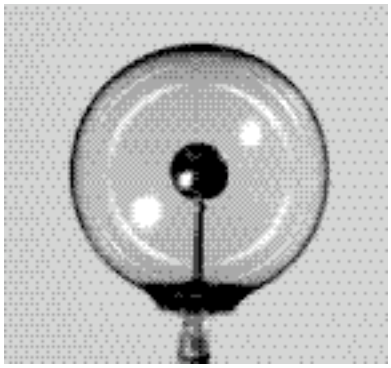

Fig. 5. Double-shell target containing an inner lining of PVA. Fabrication of seven of these first-of-a-kind targets was accomplished in six weeks.

We considered applying a layer of PVA around the rim to minimize out-permeation of the xenon through the epoxy glue joint. As that development effort would have jeopardized our delivery deadline, we decided to test the assembly for leakage as it was. We did this testing by permeation filling the targets with 1 atm of xenon at 100°C overnight. We then used our XRF (x-ray fluorescence) system to measure the quantity of xenon present in the shell immediately after the fill and over the course of 24 h as they out-gassed at room temperature. We found that the targets had fill half-lives on the order of two days duration. After consultation with our LLNL partner, it was decided that this half-life was sufficient for the targets to be fielded.

VI. SUMMARY

In the time frame of a month, we devised a unique process for lining the inner wall of a CH capsule with PVA for a new type of double-shell target. We had to first find processing conditions that allowed us to use drop tower technology to PVA-coat PAMS shells. Then we had to develop appropriate methods to remove the PAMS mandrel after the drop tower shell was coated with GDP. We fabricated and delivered seven of the new PVA-lined double-shell targets in all, meeting the needs of the experimentalists. The elapsed time from receipt of the request to delivery was six weeks.

ACKNOWLEDGMENT

Work supported by the U.S. Department of Energy under Contract DE-AC03-01SF22260.