

ASSEMBLY OF MESO-SCALE TARGETS FOR ICF EXPERIMENTS

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Introduction

Inertial Confinement Fusion (ICF) targets being developed at Lawrence Livermore National Laboratory require precision manufacturing and assembly techniques on meso-scale components. Among the difficulties is the ability to position and locate specific features during various stages of manufacture and assembly. Targets for this application are millimeters in overall size, composed of parts on the order of tens of micrometers. Fig. 1 illustrates the basic geometry of the ICF target assembly on its base. A more detailed description of the target geometry and ICF physics can be found in the text by Lindl [i]. These complex structures must be able to operate at cryogenic temperatures and withstand shock and environmental disturbances during assembly and insertion into the target chamber.

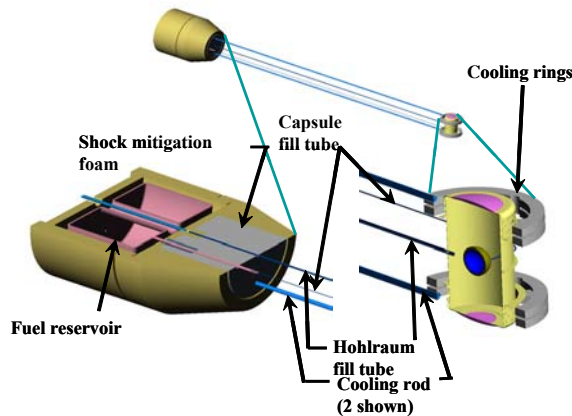


Fig. 1: Schematic diagram of the ICF target.

This abstract focuses on issues encountered during the manufacture processes and assembly techniques utilized to attach fill-tubes to ICF target capsules. The target capsules range in size from 0.5 mm to 2.4 mm in diameter with a wall thickness of between 60 μm and 175 μm . These capsules can be made of a number of different materials, but most commonly plasma polymer (CH) or sputtered beryllium depending on the application. Currently, a 10 μm diameter, approximately 2 mm long glass fill-tube is being inserted into a 20 μm to 40 μm deep, nominally 12 μm diameter counterbore and adhered to the capsule using a cryogenic epoxy. The position tolerance between the center of the through-hole and the counterbore is nominally $\pm 1.0 \mu\text{m}$. A more

detailed illustration of the required fill-tube/capsule interface geometry is shown in Fig. 2.

The focus of the work outlined in this paper include fixturing the capsule for manufacturing and assembly processes, develop the capability to create the required geometry in a beryllium capsule and assemble a glass fill-tube. The fixture itself must provide location information, secure the capsule during a number of processes and finally release the completed assembly without damage. The through-hole is manufactured using a laser [ii], while micro-electro discharge machining (EDM) and focused ion beam (FIB) milling have been tested for creating the counterbore over the through-hole.

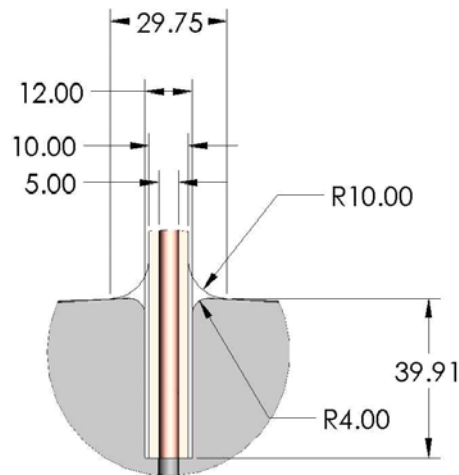


Fig. 2: Current ICF target fill-tube/capsule interface geometric requirements.

Process Plan

The processes necessary to create the geometry in the capsule and to assemble the fill-tube continue to evolve based on experience and available technologies. Table 1 lists the current process plan for manufacture and assembly of the capsule/fill-tube geometry. It is clear that temperature loads and the capability to locate and relocate position play an important role in the overall process plan. The wide range of environments seen by the fixture and sample present a challenging problem and are still under investigation.

Table 1: Current process plan for fill-tube assembly

Process	Comments
Mount capsule	Fixture needs to provide datum while maintaining capsule position
Through hole	Laser machined, difficult to locate hole for successive processes
Counterbore	Focused ion beam milling
Pyrolysis	Temperature to 500 °C
Fill tube attachment	Located using vision system and positioned using micromanipulators and air bearing spindle. Adhered using 2-part epoxy.
Remove capsule from fixture	Need to independently hold capsule and tube while being disassembled

Critical to the success of the plan is the ability to manufacture the required geometry in the proper location. Depending on the process used to create the geometry, the quality of the fixture can be varied. The micro-EDM requires much better references since the location cannot be directly determined using the EDM, while the FIB has *insitu* metrology that is able to locate the laser hole.

Fixturing

The fixture developed for mounting the capsule during the various processes is shown in Fig 3a. A conic bore is machined into the center of a cylindrical disk. The OD and face of the fixture is diamond turned and used as a datum for some of the processes performed on the capsule. In this design the preload spring pushes the capsule into the conic bore from the rear of the fixture exposing a small working section of the overall capsule area. The apparent working area depends on the final geometry of the conic bore and the overall dimensions of the beryllium capsule.

Two preload springs have been manufactured for test this approach. The first is a polyimide diaphragm 9 mm in diameter and 40 μm thick. The polyimide diaphragm is adhered to a hollow, stepped tube that is held against a shoulder stop by a fine thread set screw. Unfortunately, polyimide will not work under the extreme heat loads applied during pyrolysis. To meet the temperature requirements a second spring (see Fig 3b), of similar overall dimension was laser machined from INCONEL[®] and should allow the spring to hold its elastic properties under elevated temperatures.

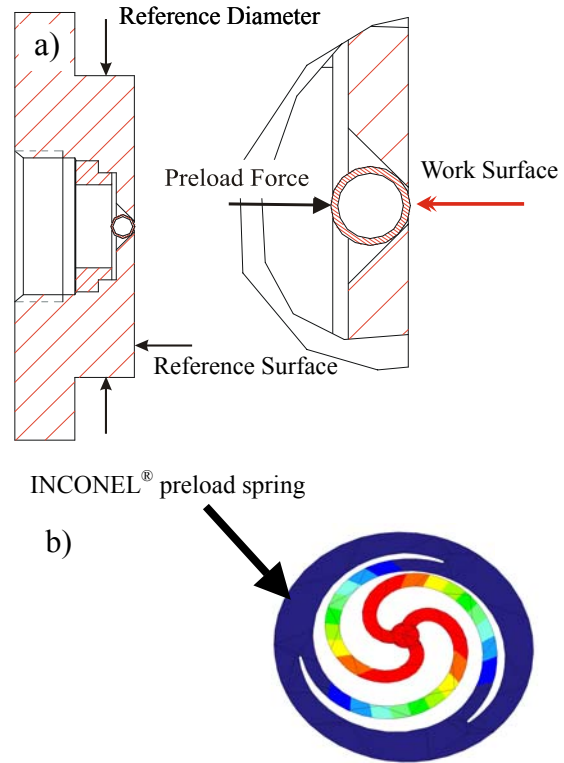


Fig. 3: a) Section view of a prototype capsule fixture illustrating the reference surfaces and capsule arrangement. b) INCONEL preload spring designed for high temperature applications.

Counterbore Manufacture

Two manufacturing methods have been undertaken to create the counterbore over the laser drilled through-hole, micro-electro discharge machining (micro-EDM) and focused ion beam (FIB) milling. Micro-EDM has been shown to produce geometries near the requirements outlined earlier in metals such as beryllium. However, the metrology of the micro-EDM makes locating the laser hole difficult due to the inability to transfer location information from the laser drilling process to the EDM at micrometer scales.

As a first attempt at micro-EDMing a counterbore over a laser drilled hole, a beryllium capsule was mounted in the fixture described previously. Following laser drilling, the hole location and datum were measured using an optical probe on a coordinate measuring machine (CMM). The laser hole was located relative to the center of the fixture determined by the outside diameter of the cylinder. Preliminary results of using the micro-EDM process are shown in Fig 4. It was clear that transfer of location between the CMM and the micro-EDM contained some error. Higher magnification

images of the fixture showed that the edge detected by optical methods and the edge detected by contact of the micro-EDM probe were not coincident, resulting in the positioning error. It is believed that this issue may be resolved by modifying the fixture geometry to better define the edge.

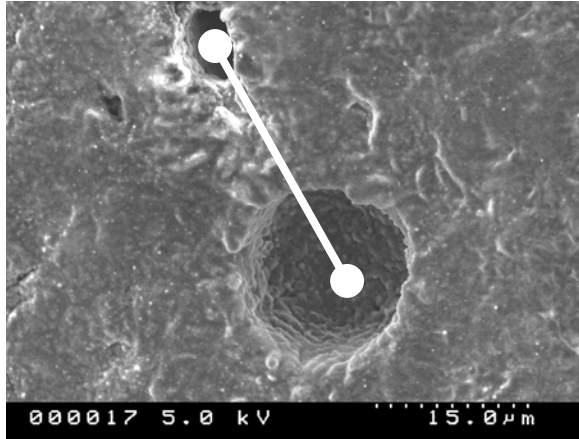


Fig. 4: Image of the 1st EDM counterbore experiment on beryllium capsule. Misalignment of center locations of approximately 20 μm .

The other method used to create the counterbore geometry was the FIB. The FIB has the advantage of having *insitu* metrology thereby allowing the user to locate the laser hole and position the counterbore with relative ease. Potentially, this would alleviate the problems seen during the EDM experiments with little or no penalty. However, the ability to create the required geometry without clogging the laser through-hole is still under investigation. Fig 5 illustrates a FIB milled counterbore over a laser drilled hole in a beryllium disk.

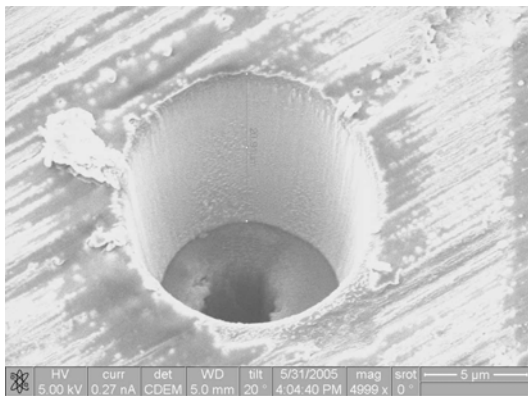


Fig. 5: Image of FIB milled counterbore over a laser drilled hole in a beryllium disk. Approximately 12 μm diameter at the top and 8 μm diameter at 24 μm deep.

Fill-Tube Assembly

Assembly of the fill-tube into the counterbore is done using feedback from two imaging systems that allow the operator to center the counterbore and then locate the tube tip. The tube is then brought into contact with the surface of the sample until the tube deflects. At the micrometer scale the glass tube is fairly flexible and can be somewhat robust. Epoxy is applied to the tube using a micropipette and then inserted into the counterbore. Presently, this technique is being used to adhere a fill-tube to CH capsules for diagnostic shots on the Omega laser in Rochester. Issues concerning sealing and possible wicking of the adhesive up the tube are ongoing.

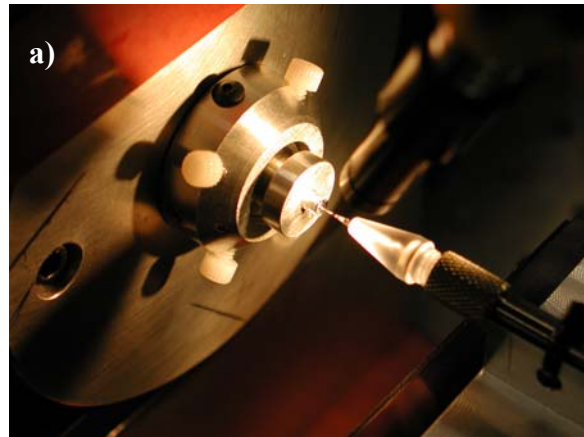


Fig. 6: a) Illustrates the set-up for fill-tube insertion into the counterbore. b) Glass fill-tube inserted and adhered to a 12 μm diameter, 10 μm deep counterbore in an aluminum test sample.

Conclusions

A predominant issue throughout the manufacture and assembly of ICF targets is the ability to transfer positional and dimensional information from one process to another at the micrometer or smaller level throughout a number of processes. Accurate characterization and fixturing of mesoscale parts and assemblies presents a gap in current metrological applications.

Acknowledgments

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- [i] Lindl, J, *Inertial Confinement Fusion: The Quest for Ignition and Energy Gain Using Indirect Drive*, AIP Press, 1997.
- [ii] Armstrong, J.P., Stuart, B.C., Rubenchik, A.M. and Gunther, J., Micron-Scale Deep Hole Drilling For Metallic Capsule Fill Applications, *Fusion Science and Technology*, submitted for publication 2005.