Manufacture and Assembly of shell-and-cone targets for plasma collision experiments

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Introduction

This article will give a brief introduction to complex shell-and cone-targets Scitech Precision Ltd assembled for an experimental campaign involving the collision of plasmas.

The main purpose of the experiment was to drive the target from two sides using two nanosecond lasers. The plasma that is ejected from the cones collides in the middle which is observed. Diagnostics used were proton radiography and hard x-ray measurements.

Target and manufacture

There were three main constituents for the target: a gold micro cone, a plastic micro hemisphere and an aluminum mount, all of which were precisely machined, assembled and characterized.

Gold micro cone

The micro cone was the first part of the target to be made (see Figure 1). The gold micro cone was a wall thickness of ~20 µm as shown in Figure 2. The gold was electroplated on to a copper mandrel which was single-point diamond turned. Once the correct thickness of gold was plated the edge of the mandrel was machined off to leave the required length for the micro cone. The copper was etched out using nitric acid leaving just the micro cone with a height of ~380µm.

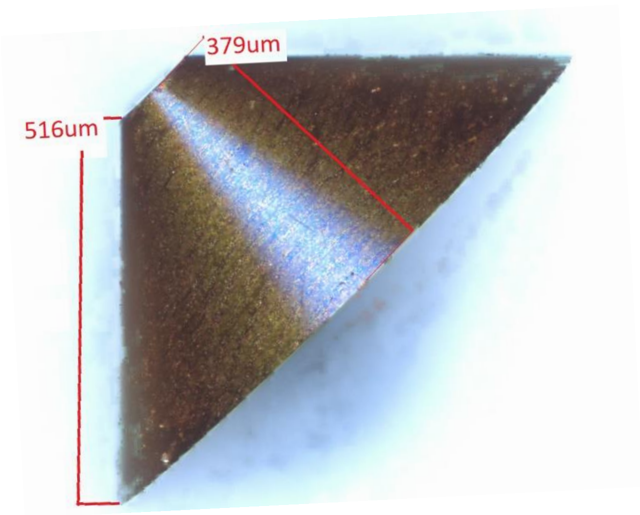

Figure 1: Image showing a completed micro cone. The height was ~ 380 µm and the radius on the mouth of the cone was ~100 µm

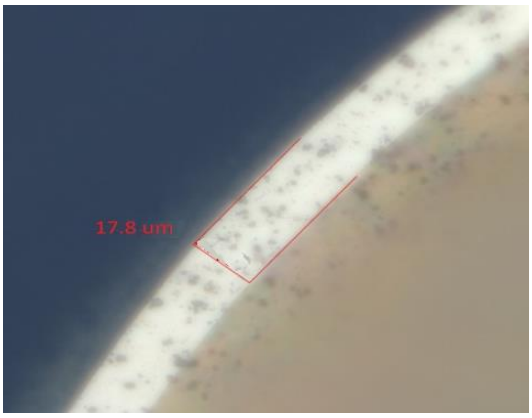

Figure 2: Image showing the ~20 µm wall thickness of the gold

The plastic hemisphere

The next step in the production of the target was positioning a plastic micro hemisphere inside the gold micro cone. The plastic hemisphere was 60 µm parylene C (PyC) and 1 µm of deuterated plastic coated on top of the PyC. The parylene C was coated by a chemical vapor deposition method on to an aluminum mandrel. Physical vapor deposition was used to coat the deuterated plastic (see Figure 3). The required length along the mandrel was then lathe machined to size and the plastic peeled away to obtain the plastic hemisphere.

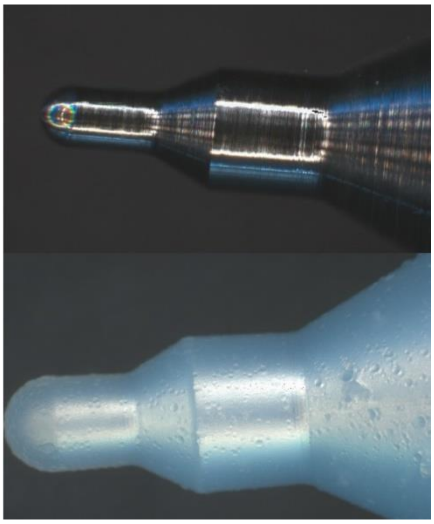

Figure 3: Top image shows a machined aluminum mandrel prior to CH coating. The image on the bottom shows the same mandrel after 60µm of parylene C and 1µm of CD plastic was coated. The tip of the mandrel was machined off to obtain the hemisphere.

Aluminum bridge

A complete target consisted of two micro gold cones facing each other both with a micro hemisphere placed inside each cone. An image of a complete target is shown in Figure 4.

The two cones were attached to an aluminum bridge which was laser machined at Scitech Precision Ltd. The bridge was designed to have a 100µm spacing between the two cones which defined the plasma interaction area.

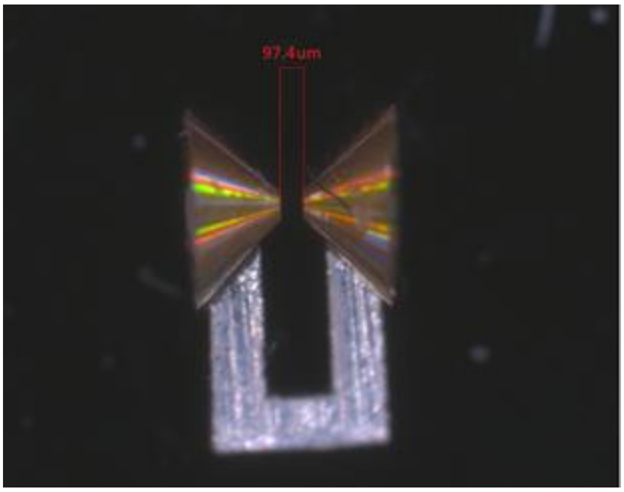

Figure 4: Image showing a completed target. The aluminum bridge holds the whole assembly together and controls the cone spacing.

Target fabrication techniques

The target was a complex precision assembly which required several target fabrication techniques. Figure 5 briefly mentions some of the processes.

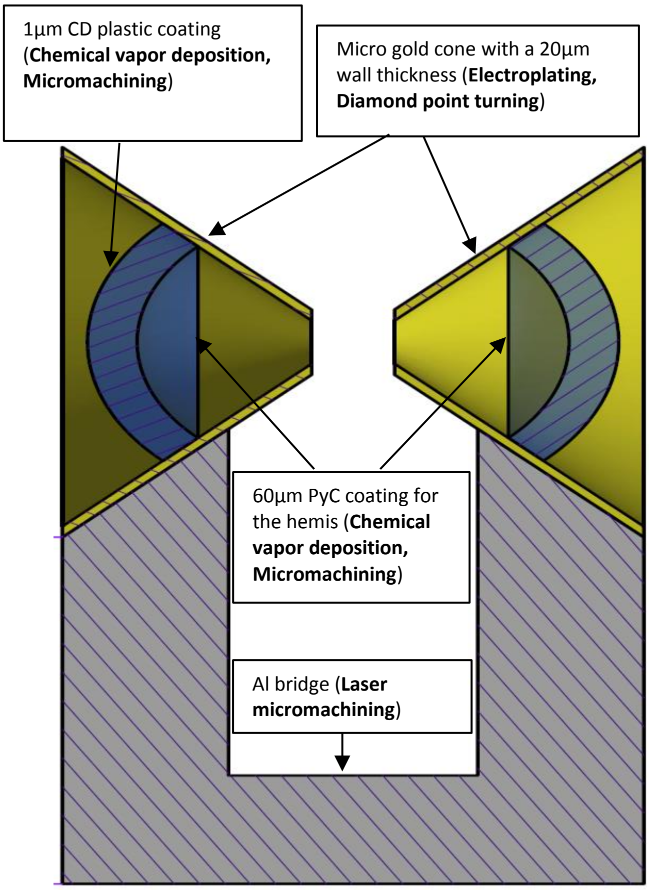

Figure 5: Drawing showing the full target

Brief descriptions of the fabrication methods are as follows.

Electroplating is a process in which a thin layer (typically of metals) can be coated on to a surface of an electrode by electrolysis. In this target the copper mandrels were plated with gold up to 20µm thick.

Diamond point turning (DPT) produces surface roughness of down to a few nanometers. For this project DPT was used to machine the gold cones to size (≈380µm in length) as well as to machine the plastic hemispheres.

Laser micromachining allows the machining of very small target components with a resolution of about 10µm. The scope of this project did not require such high tolerances, however, having the capability is crucial for machining components for use in high power laser experiments.

Physical vapor deposition (PVD) is one of the main techniques of thin film coating typically by subliming the source material using a heat source. The nature of PVD allows for a uniform deposition of material onto the target surface. The method was used to coat the deuterated plastic. Chemical vapor deposition was used for coating of PyC. In the case of PyC the parylene dimer is cracked into a monomeric form in a high temperature furnace which, when reaching the cool coating chamber coats evenly as a polymer on the target surface.

All above techniques combined with micro assembly are necessary in the production of the complex targets.

Challenges and assembly

The task of assembling this specific target was very challenging. The thinness of each component meant the handling of each was difficult. Very light pressure was required in order to not damage the very fragile components. A big challenge was working out how to hold the cone without damaging it and subsequently applying a minimal amount of adhesive and placing the hemisphere in the correct orientation before it set.

We had to closely monitor and control the environment of the assembly area to ensure no contamination was deposited on the target and to ensure that the assembly tolerances could be met.

The gap between the two cones on the final targets had to be 100µm±5µm which is a very exacting requirement. The challenge was overcome with the design of the laser machined aluminum bridge which allowed the cone separation to remain within tolerance in all targets.

Future improvements

The targets achieved the high specification required for the experiment. However for similar experiments in the future there are several improvements that should be investigated. The quality of the targets could be improved if an assembly jig can be machined ideally using additive manufacturing processes. The jig could significantly ameliorate the problem faced when handling the gold cones. A jig could be developed to hold all the separate microcomponents required for the complete target.

Conclusions

Scitech Precision Ltd received a request to fabricate and deliver complex shell-and-cone targets. The micro cones had a wall thickness of 20µm which made handling very difficult. A 60um thick plastic hemisphere was glued inside the gold micro cone. Subsequently two such cones were attached to an aluminum bridge with a 100µm± 5µm gap to complete the target. Many different processes were used in the development of the targets which included diamond point turning, PVD, CVD and laser micro machining as well as complex manual assembly.