Microassembly of Buried Wire Targets for the European XFEL

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Introduction

The European X-ray Free Electron Laser (XFEL) is the world's largest X-ray laser. It generates ultrashort X-rays flashes with a brilliance that is a billion times higher than that of conventional X-ray sources.

To generate the coherent X-ray flashes, electrons are accelerated within a special magnet arrangement. In the process particles emit radiation that is amplified until an intense X-ray pulse is created. [1] XFEL opens up research into a whole host of new areas with atomic precision.

When such machines are operational the instrumentation that is developed for detection must be of the highest performance. Scitech Precision Ltd [2] were contracted to fabricate buried wire targets to be used to test some of the XFEL detectors. Additionally the targets were used to study the physics of planetary interiors.

The Target

In the experiment, scientists were interested in the transport properties and hydrodynamics at a metal/plastic interface in warm dense matter.

To create matter in the regime of interest, the microtargets requested were an ultrathin (4 µm diameter) tungsten wire coated with 50 µm (100 µm total) of plastic.

The experiment consisted of irradiating the outside of the plastic cylinder with a high-intensity short pulse laser. The hot electrons generated by the interaction of the short pulse laser with the tungsten target isochorically heated the target on a very short timescale creating a temperature differential at the interface between the tungsten wire and plastic. The density profile of the interaction was measured with high-resolution phase contrast imaging.

Figure 1 shows a schematic of the target requested. The target consists of three main components each of which requires a different technology for fabrication. Each target is also mounted on an aluminium target mount.

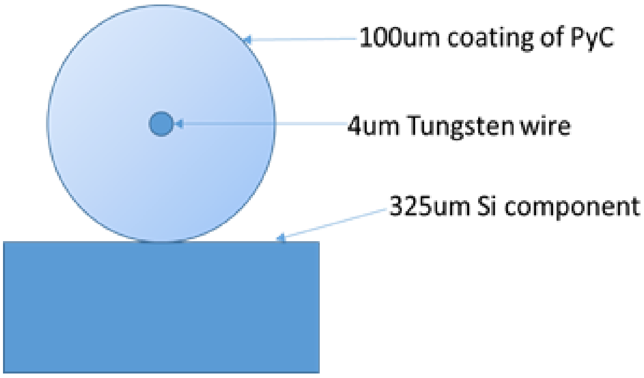

Figure 1: Schematic of the target which consists of a thin wire (4 µm diameter shown) coated in 50 µm (100 µm diameter) of Parylene C (PyC)

Diagrammatically the target looks simple, but its fabrication required a considerable amount of microfabrication expertise. Four target mounts were fabricated, two with 4 µm (diameter) tungsten wire and two with 10 µm tungsten wire, with 4 µm proving the most challenging.

Target Fabrication – 3D printing

The initial proposal for developing the target was to use MEMS (Microelectromechanical system) techniques. The plan was to etch down 4 µm on tungsten (to give the required thickness) and then coat with plastic, but this would have been a very lengthy and costly process. The reason for the initial MEMS approach was to avoid the considerable mechanical challenge of mounting such thin wires inside a parylene coating plant chamber. However, due to the cost and time required for the MEMS approach, an alternative mechanical assembly method had to be found. Part of the solution was to use additive manufacturing.

A plastic pillar jig, as shown in Figure 2, was additive manufactured using the in-house 3D printer. The 4 µm wire was mounted by hand across the pillars and bonded in situ with UV cure glue. The mounting process comprised bonding the wire on one end pillar, applying the glue to the second pillar, pulling the wire gently across with tweezers, and then curing the glue using a UV gun when the wire was fully straight. Due to the thickness of the wire the method took a lot of patience, because the wire would snap frequently.

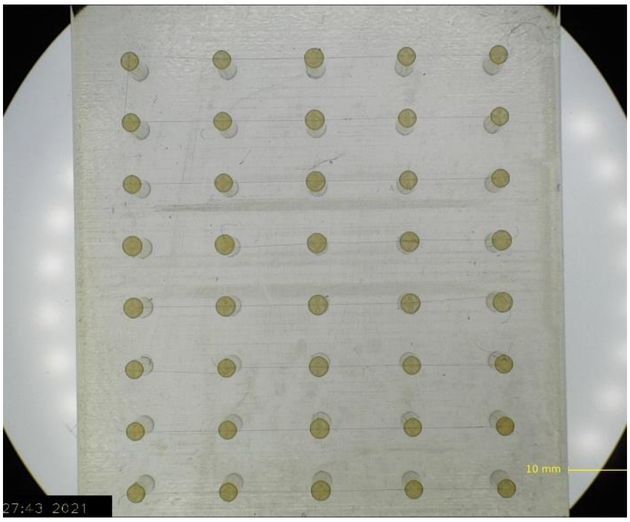

Figure 2: The 3D printed pillar structure with the 4 µm wires pulled across rows prior to parylene coating

Target Fabrication – Parylene coating

Parylene is an industry name for a unique polymer series that has an aromatic carbon-hydrogen molecular structure. [3] (Parylene provides excellent moisture, chemical and dielectric barriers, and in industry it is mainly used in electric circuits.) Within target fabrication, parylene is generally used as a pusher foil in a target to help create a shock, as was the case for this specific target. There are several versions of parylene – such as Parylene N, Parylene C, Parylene D – each with unique chemical and physical properties. For the project, Parylene C (PyC) was requested (which has a fast coating rate of approximately 5 µm per hour).

The process for parylene coating is as follows:

- The process begins with the parylene dimer in powder form.
- The powder is heated to 150°C converting the dimer from solid to vapour.
- In the next (pyrolysis) stage the dimer vapour is further heated in a furnace to a temperature of up to 650°C which breaks the dimer molecules into monomers.
- The final stage is the deposition process itself. The samples to be coated are mounted in a chamber that is under vacuum. The pressure difference between the chamber and the furnace pulls the monomer out to the chamber. The chamber is at room temperature and the monomer vapour spontaneously polymerises onto the cooler substrates and surfaces.
- An even coating of parylene is deposited on all the surfaces within the chamber.

To build up the 100 µm diameter of parylene on the tungsten wire, a total of 50 µm was coated. Because parylene coats in a highly conformal manner, the 50 µm was coated around the wire, giving a diameter of 100 µm (+ 4 µm) as the final thickness.

Target Fabrication – Characterisation

After the wires were coated, the next stage was to image all the PyC coated wires and pick the ones that were straight. Due to the weight (and perhaps internal stresses) of a 100 µm thick coating on a 4 µm wire, some wires twisted during the fabrication process. An optical microscope was used to examine the coated targets and pick the acceptable ones, as seen in Figure 3.

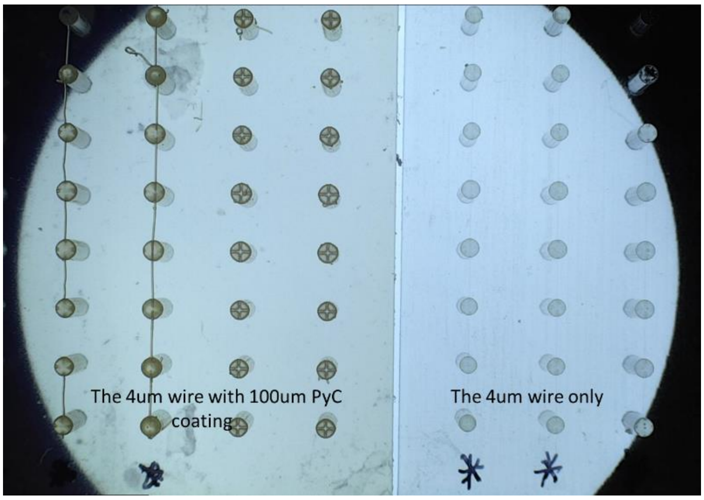

Figure 3: An optical image comparison of the mounted 4 µm wires post- and pre- PyC coating. The lighter half on the right is before the coating and the left shows after the 50 µm PyC coating.

Thickness measurements were taken after the microtargets were fully assembled. Characterisation is generally one of the most important aspects of target fabrication, because after a target is shot further measurements are impossible.

Target Fabrication – Laser micro machining

One other component of the target was a 325 µm thick silicon wafer spacer, to which the tungsten wire assembly was attached. Using a femtosecond laser, a silicon wafer was machined to produce suitable mounts.

Target Fabrication – manual assembly

After each individual wire had been supported on its spacer, the final target array was produced by manually assembling them on an aluminium mount (as shown in Figures 4 and 5).

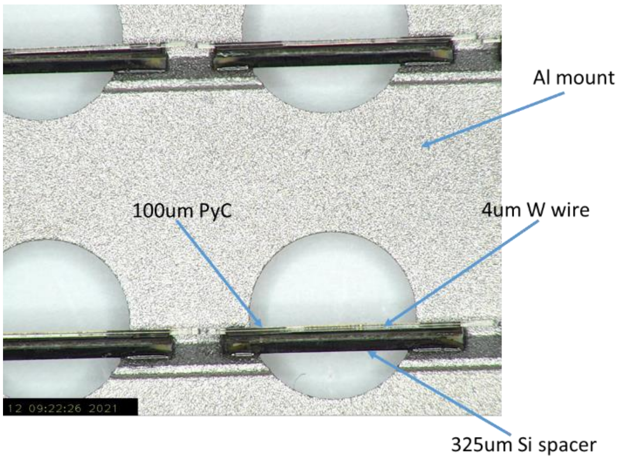

Figure 4: An optical image of the completed assembly mount showing the three parts of the completed target

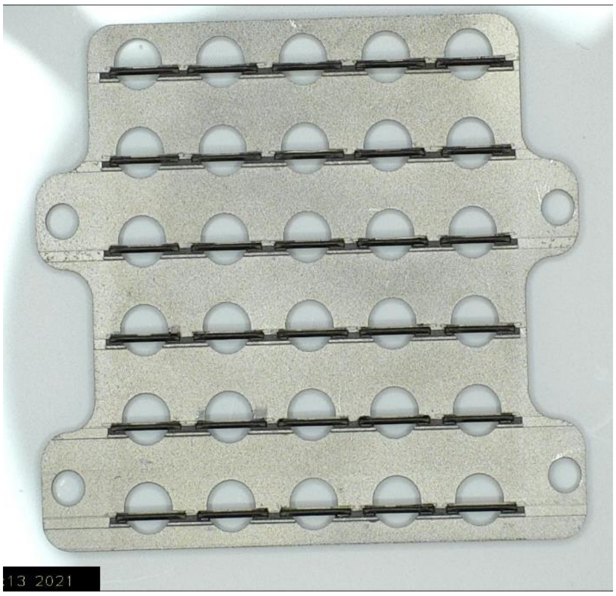

Figure 5: An optical image of the full target mount

Target fabrication techniques

The targets produced within Scitech Precision and the Target Fabrication Group go through multiple stages as they are progressed from concept to final, quality-assured targets. The target described in this paper required the combination of laser micromachining, chemical vapour deposition (PyC coating), characterisation (optical imaging, profilometry), additive manufacturing, and micro assembly.

The main challenge in the fabrication of the target was in establishing a reliable technique to coat 50 µm (100 µm total) of PyC onto the 4 µm diameter tungsten wire.

Conclusion

Scitech Precision were tasked with fabricating buried wire targets for studying the transport properties and hydrodynamics at a metal/plastic interface. The targets were used to test some of the detectors at XFEL, as well as being used in planetary science experiments. Four target mounts were fabricated: two with 4 µm diameter tungsten wire and two with 10 µm diameter tungsten wire. The 4 µm diameter tungsten wire targets proved most challenging. In all cases the wires were coated with 50 µm (100 µm total) of Parylene C. The experiments at the European XFEL were successful.

References

[1] EU XFEL: https://www.xfel.eu/facility/overview/index_eng.html

[2] Scitech Precision Ltd: http://scitechprecision.com/

[3] SCS coatings: https://scscoatings.com/parylene-coatings/parylene-properties/