Developing and manufacturing cone targets for the CLF

M. Beardsley and J. Spencer
Millimetre Wave Precision Development Facility, CCLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxon., OX11 0QX, UK

M. K. Tolley and C. Spindloe
Central Laser Facility, CCLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxon., OX11 0QX, UK

Main contact email address m.k.tolley@rl.ac.uk

Introduction

In the Space Science and Technology Department at RAL the Millimetre Wave Precision Development Facility specialises in researching and developing techniques that are required to manufacture high precision micro-components. For a number of years this Facility has worked in collaboration with the Target Fabrication Group of CLF to develop and manufacture microtargets for use in high power laser experiments. This collaboration has yielded a wide range of benefits to the engineering and scientific communities within both CCLRC and external institutions and companies.

The range of microtargets resulting from the collaboration have enabled experiments to be performed which investigate new areas of science. Specifically the manufacture of miniature gold cones for use in Advanced Fast Ignition (AFI) experiments required the utilisation, development and combination of innovative processes. The core techniques are a development of those used to manufacture precision microwave feedhorn antennas. This report is a brief overview of the process required to manufacture cones incorporated into microtargets used in AFI studies [1,2,3].

Mandrel Manufacture

The process starts with the high precision lathe turning of a copper mandrel onto which the internal profile of the cone and a number of reference features are machined. The features provide datums used during subsequent machining of the cones after gold plating. An example of a finished copper mandrel is shown in Fig. 1.

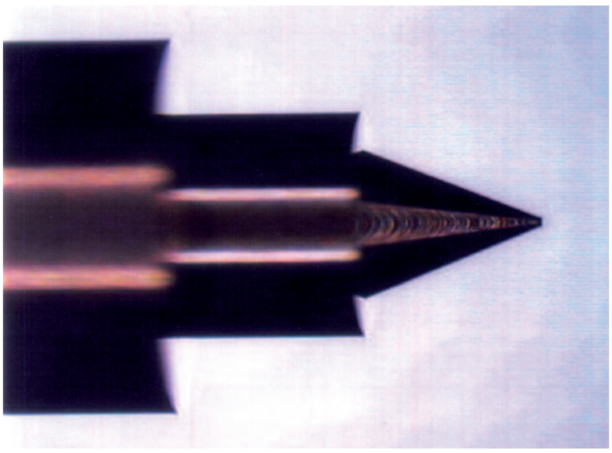

Figure 1. Copper mandrel with datum surfaces machined.

Inspection During Manufacture

Due to the very small size of the components optical inspection can only be achieved using very high power microscopes. (Typical cone dimensions are; length 1mm, base external diameter 400 µm and tip end wall diameter 60 µm.) To obtain accurate measurements the cones are measured on a co-ordinate measuring machine which optically recognises features and is accurate dimensionally to the micron level. When all the necessary metrology information has been recorded the mandrel is masked off leaving only the area to be plated exposed.

Figure 2. Inspection of a mandrel using on optical co-ordinate measuring machine.

Plating and Etching

Gold is electroplated onto the copper mandrel in a high purity gold cyanide plating bath. The plating can typically take several days. (A fully plated example is shown in Fig. 3.) When sufficient gold has been electroplated onto the mandrel the part is replaced on the lathe and the outside profile of the cone is machined. This is done referring to the datum points on the mandrel to accurately locate the part. To avoid damaging the soft gold material and also to be able to produce (in some cases) a 3 µm end wall thickness a tool much sharper than a hypodermic needle has to be used. After the external profile of the cone has been machined the production process finishes with the gold cone, still on its copper mandrel, being placed in a solution of nitric acid. The acid etches away the copper leaving the finished gold cone.

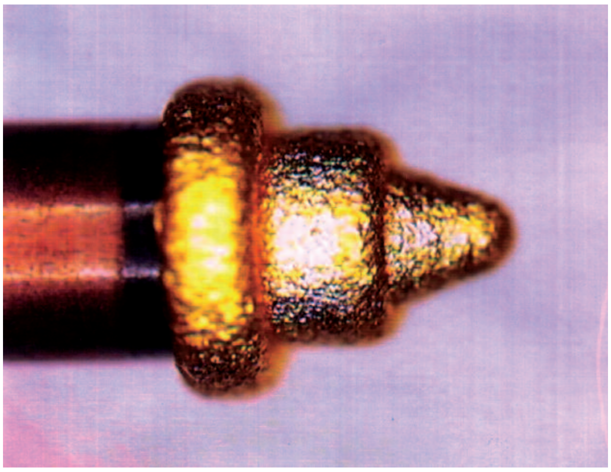

Figure 3. An electroplated part showing the gold deposit on the copper mandrel.

Characterisation of Finished Cone

To check the form profile one cone (still on its copper mandrel) was sectioned along the centre. The sectioned part was then lapped and lightly etched in nitric acid before being inspected. In figure 4 the sectioned cone is shown and the profile can clearly be seen. Again using the co-ordinate measuring machine it was possible to optically measure the profile of the cone including the tip wall thickness. Subsequently the copper mandrel was fully etched from the sectioned cone enabling SEM inspection of the internal wall quality.

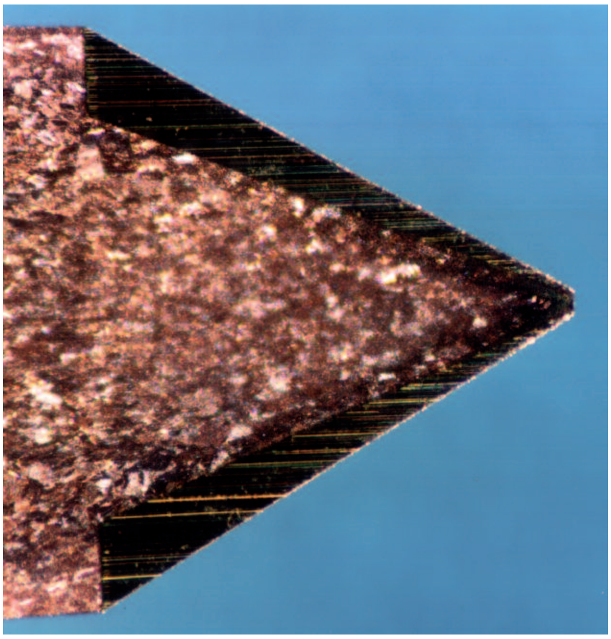

Figure 4. Sectioned and polished cone still on mandrel.

Design Variations

Ultimately cones of a similar design to those discussed above will be incorporated into AFI-type laser driven fusion targets. In such targets the cone is mounted through the side of a fuel pellet. A complete (non-cryogenic) AFI target is shown in Figure 5.

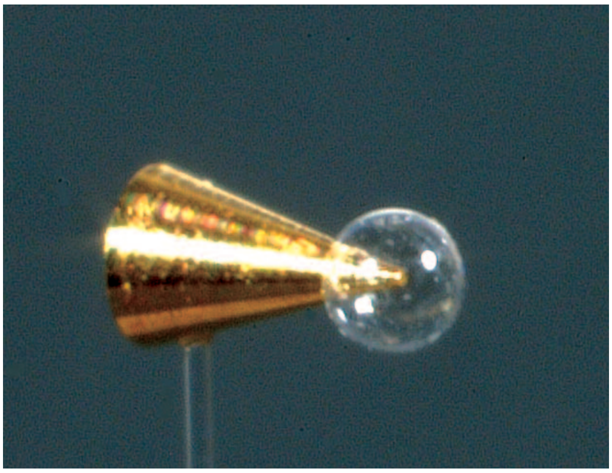

Figure 5. AFI Target (non-cryo).

To support AFI studies a range of experiments have been performed to enable a better understanding of the behaviour of laser driven cones. Throughout the time that the Millimetre Wave Precision Development Facility has been producing cones for the CLF a number of different variations of cone design and cone target components have been fabricated. Amongst other variants the cone production machining processes have been modified to produce; a) a range of tip wall thicknesses, b) a range of cone angles, c) profiled end walls. Also, stand off tubes have been micromachined enabling a (multilayer) foil package to be positioned with micron accuracy relative to the cone tip. One such assembly is shown in Figure 6.

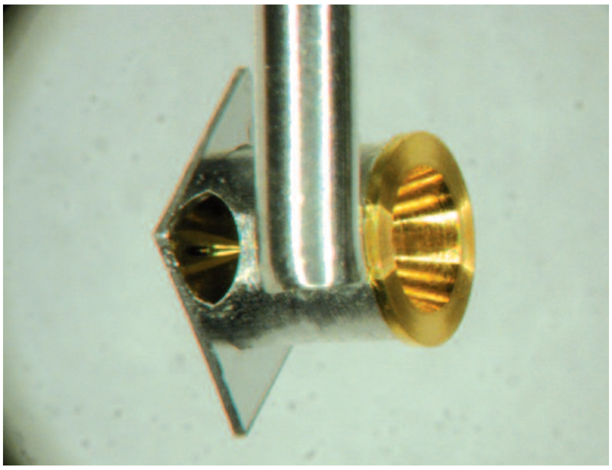

Figure 6. A fully assembled AFI target with stand off tube and foil package. The reflection of the cone tip can be seen in the foil.

References

1. P. A. Norreys *et al., Physics of Plasmas* **7**, 3721 (2000)
2. R. Kodama, *et al., Nature* **412**, 798 (2001)
3. R. Kodama *et al., Nature* **418**, 922 (2002)