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Recent Development of Target Fabrication and Fuel Layering Technique for FIREX project

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Abstract. Several key issues for fabrication and fuel layering technique of cryogenic target for Fast Ignition Realization Experiment (FIREX) project have been developed. From the viewpoint of enhancement of coupling efficiency on the fast heating and improvement of the implosion performance some advanced modifications for the target design have been proposed. Although the error of assembling the cones is still several microns, a double cone target with the vacuum gap of 20 micron was successfully provided for the preliminary experiment. Fabrication of low-density plastic shell and their mass production technique using new devices have been developed. Furthermore, for the fuel layering, the new technique of conical laser guide heating has been proposed to realize a uniformly fuel layer.

1. Introduction

The first phase of the Fast Ignition Realization Experiment (FIREX-I) project of ILE, Osaka University is to demonstrate efficient heating of properly compressed fuel plasmas. Based on previous preliminary experiments[1] using polystyrene shells with a gold conical light guide for additional heating, the basic target shown in Figure 1 has been designed for the FIREX-I project.

Experimental and theoretical studies of the heating mechanism, the coupling efficiency of the laser with electrons, and the coupling of this to the core thermal energy have been investigated[2-7]. On the basis of these studies, a new advanced target for FIREX-I[8] has been proposed and is schematically illustrated in Figure 2. In this design, the following modifications are adapted.

1) Double cone.
2) Low-Z foam layer on the inner surface of the gold cone.
3) Low-Z plastic layer on the outer surface of the cone.
4) Br doped plastic shell.
5) Evacuation of the target center.

The coupling efficiency is expected to increase because of 1) and 2)[4, 5], while the implosion performance is expected to be increased because of 3), 4), and 5)[6, 7].Figure 3 shows a picture of double cone target and a cross-sectional view of cone tip part taken by x-ray radiography

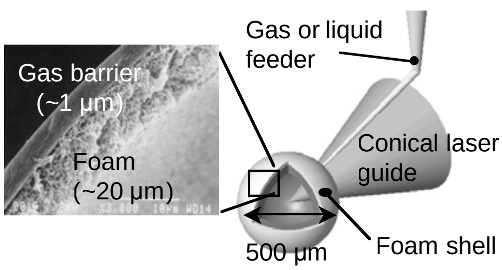

Fig. 1 Basic target design for FIREX-I.

In this paper, recent developments on fabrication process of double cones and low-density materils for capsule, and fuel filling sequence for cryogenic target are reported. The other modification points for advanced target metioned above will be dicussed in future works.

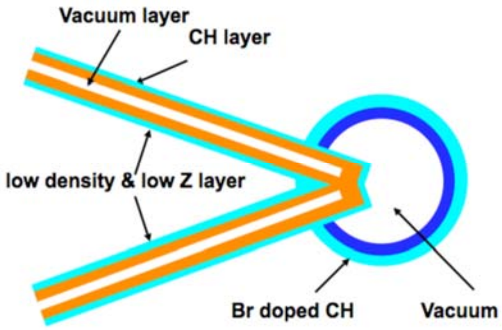

Fig. 2 Advanced design of FIREX-I target.

2. Fabrication of double cone target

A fabrication technique of the double cone has been developed. Figure 3 shows the cross-sectional illustration of the design for first prototype of the double cone, with a 20 μm vacuum gap between the two cones. The both of gold cone were made separately by an electrochemically plating technique. A $Cu_{60}Zn_{40}$ alloy was adopted as substrate material for the gold plating process because of its machinability and solubility in acid. First, the molds were made by two-steps of turning machining. In the rough machining process, a byte made from high-strength steel was used, and a diamond byte was used for precise machining.

The gold plating on mold surface was carried out electrochemically with potassium dicyanoaurate solution. An electrochemical cell was equipped with the Cu-Zn substrate electrode, a gold counter and a Ag/AgCl (in saturated KCl electrolyte) reference electrode. Applied potential was adjusted by using a potentiostat (Hokuto Denko, HABF501) with a function generator and a coulomb meter. The electrolyte for gold plating was prepared as follows; 2.0g of $KAu(CN)_2$, 1.0 g Na_2EDTA, and 10 g of triethylenetetramine were dissolved in 100 ml of water. Aqueous 1,1-hydroxyethane-1,1-diphosphonic acid (60 %) solution was added into the solution. If the solution becomes acidic, slight amount of NaOH aqueous

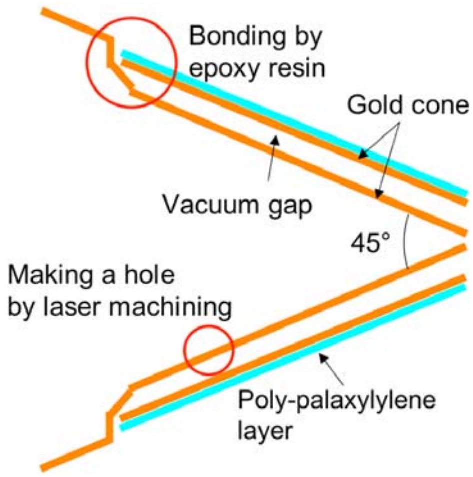

Fig. 3 Schematic illustration of design for the first prototype of double cone for advanced target for FIREX-I.

solution was added to adjust pH=6.5. The electrolyte was kept at 338 K during the electroplating. In this process, the thickness of gold layer was controlled to be 10 μm by measuring the integrated electric charge during plating. After that, a v-shaped notch was carved around surface of gold-plated mold at prescribed length from cone tip. Finally, the gold-plated mold was immersed into iron nitrate aqueous solution to dissolve the mold. The outer surface of the outer cone was coated with poly-palaxylylene before etching process. A hole was bored in prescribed part of inner cone by laser machining. The vacuum gap was exhausted through this hole in experimental chamber. After finishing of preparation of all components, the target was assembled using a XYZ manipulator.

Figure 4 (a) shows a picture of double cone target, and (b) shows a cross-sectional view of cone tip taken by x-ray radiography. This target consists of inner gold cone, outer gold cone covered with poly-palaxylylene and polystyrene (PS) shell (500 μm in diameter, 7 μm in thickness). Measurements from the x-ray radiograph show that the width of vacuum gap is from 8 to 14 μm near the cone tip, and thickness of gold cones were almost 20 μm. The width of vacuum gap was smaller than prescribed value, because of the thickness of gold cone was two times thicker than prescribed value. The error of cone thickness seems to depend on the non-uniformity of electric charge distribution owing to the geometrical shape of mold. Although this error was acceptable for the preliminary experiments, we need to develop the technique of controlling the thickness of gold layer to make thinner vacuum gap.

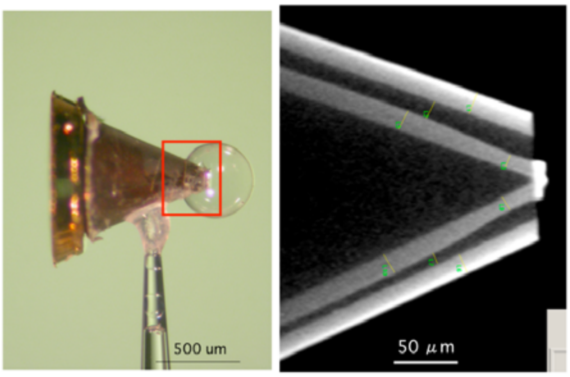

Fig. 3 Double cone target and cross-sectional view of cone-tip. (without alminum plate)

3. Fabrication of low-density plastic capsule

In this paper, we report development of fabrication process of low-density plastic capsule and its scaling to the future mass production method by using microfluid technology. For the FIREX-I project, a foam cryogenic target was designed where low-density foam shells with a conical light guide will be cooled down to the cryogenic temperature and will be fueled through a capillary. The required diameter and thickness of the capsule are 500 micron and 20 micron, respectively. New materials have been investigated for the low-density plastics capsules. By the use of a new high viscosity polymer we succeed to prepare the capsules matched to FIREX-I requirement without crosslinking. The fueling test has been started, now [2].

As for mass production of the capsules, we have studied microfluid devices to prepare compound emulsions with monodispersity of the diameter and thickness of the capsule [3]. The microfluid device provides various kinds of polymer capsules including photonic crystal beads, etc [4]. Recent improvement of our technique gave much more simple structure with T connectors of the millimeter tubes and more stable operation of the device.

4.Fuel layering sequence

In this paper, we propose a new procedure of fuel layering for the cryogenic target and report about the demonstration results. That is a conical laser guide heating technique. FIREX-I target is consisted with a polystyrene (PS) shell, a glass tube for fuel feeder, and a conical gold cone for laser guide. To fill the liquid hydrogen fuel, the target is warmed up to the hydrogen melting point and the liquid is introduced into the target capsule. After that, the target is cooled and the fuel is solidified. When liquid hydrogen is fed into the shell, it also exists around the conical laser guide because of the large surface tension of the liquid hydrogen. After that, the target is cooled down and it is solidified. Figure 4 shows the solid-hydrogen layer in PS shell. The conical laser guide is heated by the laser light so that the solid fuel is melted and moved to the other interior of the shell. This post-process is important because we can prepare solid hydrogen free area around the conical laser guide. This also help to make a uniform thick layer of the fuel for the FIREX target.

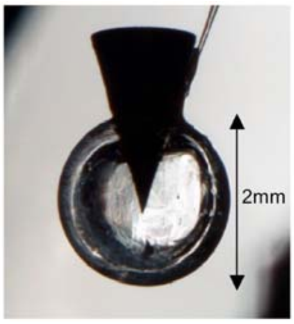

Fig. 4 Solid-hydrogen layer formed in PS shell

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