Fabrication of Tungsten Step-Wedge Filters for Use in X-Ray Plasma Diagnostics

CNF Project # 1049-02
Principal Investigator: Dr. David Hammer
User: Kate Bell

Affiliation: Electrical & Computer Engineering, Laboratory of Plasma Studies, Cornell University
Primary Funding: Department of Energy
Contact: dah5@cornell.edu, ksb42@cornell.edu

Abstract
Calibrated density and structure measurements of tungsten (W) plasmas that develop around exploding wires have been obtained through the use of x-ray radiography and a set of thin W layers that were deposited onto 12.5 µm titanium (Ti) foils. The deposited W varied in thickness in discrete steps ranging from 150 Å to 1.1 µm, creating x-ray filter “step wedges.” The Ti foils with W step-wedges were placed immediately in front of film exposed to a burst of x-ray radiation that passed through the W exploding-wire plasmas. From the exposure level of the film as a function of position, the plasma density profile in two dimensions was obtained by comparing the x-ray attenuation through the exploding wire plasmas with the attenuation through the steps of the step-wedges. An example of such a film is shown in Figure 1, with the images of step-wedges located along the left and right edges of the film and the image of the plasma produced by 10 exploding wires occupying most of the rest of the film.

Summary of Research
Density and structure of dense (> 10¹⁸/cm³), hot (10⁴ - 10⁵ K) plasmas are challenging to measure directly, but are necessary pieces of information in studies of high energy density plasmas. One method of obtaining density profile measurements is through the use of images obtained using a point source of x-ray radiation to expose a piece of film after passing it through the plasma to be measured. In order to be able to convert the x-ray absorption as a function of position on the film into a calibrated plasma density, an adjacent part of the film needs to be exposed to x-rays that have passed through step-absorbers having known thickness and made from the same material as the plasma [1].

In these experiments, carried out in Cornell’s Laboratory of Plasma Studies, a 1MA, 100 ns rise time, 200 ns duration current pulse was used to explode a cylindrical array of ten W wires, each with a diameter of 25 µm. The development of plasma around the exploding wire cores, and the self-magnetic-field-driven implosion of that plasma to the cylindrical axis of the array was studied. The backlighting radiation, taking into account Ti filter and the step-wedges, consisted of 2.5-10 keV photons produced by a molybdenum wire X-pinch [2]. An example radiograph is shown in Figure 1, and a density profile obtained using the step-wedges to calibrate it is shown in Figure 2.

The W step-wedges were created using the CVC Sputter Deposition System at the Cornell NanoScale Science and Technology Facility. Seven layers of thin W were deposited onto 12.5 µm Ti foils. The total deposited W thickness was varied in discrete steps over the range 150 Å to 1.1 µm with variations not exceeding a few percent. Steel masks were employed to ensure deposition at the desired position on the foils.

The quantitative density profiles obtained using the step-wedges are a major portion of the Ph.D. thesis of Jonathan Douglass, who is expected to complete his dissertation during the Fall of 2007 [3].

References
Figure 1: Radiograph of the plasma generated by exploding wires in a wire-array z-pinch experiment initiated from ten 25 μm diameter, 8 mm long W wires in a 12 mm diameter circular configuration. The image, which includes one step-wedge on each side of the array (on the right and left edges of the film), was obtained 140 ns after the start of a 1 MA, 100 ns (zero-to-peak) current pulse that is equally divided among the ten wires. The dark rectangle indicates the location that the density profile shown in Figure 2 was taken from the radiograph.

Figure 2: Calibrated ion density profile from Figure 1. (Notice that absorption of x-rays before reaching the film is proportional to the density of the plasma integrated along the path of the x-rays. As such, the profile is in number per cm² rather than number per cm³.)