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Two dimensional particle-in-cell simulation of plasma immersion ion implantation into the inner surface of a bore using an auxiliary electrode

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Inner surface modification of many industrial components, such as dies, bushings, pipes, etc. using plasma immersion ion implantation (PIII) is of practical importance and has attracted the attention of physicists and materials scientists [1-4]. One drawback of PIII of inner surfaces is low ion impact energy [5,6]. It has been shown that by inserting a zero potential conductive auxiliary electrode along the axis of the implanted cylindrical tube, the average ion impact energy can be raised [7]. It has also been determined that the normalized auxiliary radius should range from 0.1 to 0.3 in order to maximize the dose and produce a larger number of ions with high impact energy [8].

In this article, we use a two-dimensional particle-in-cell (PIC) model [9] to investigate realistic cases in two dimensions, such as the important and practical situation when the cylindrical tube is of a finite length. The vertical cross section of the cylindrical bore and auxiliary electrode is depicted in Fig. 1. Various ratios of tube lengths against tube diameters are simulated. It is found that a peak in total accumulated dose is observed near the ends of the tube. Provided that it is long enough, the ions come from the outside of the tube cannot pass through the middle-plane. That is, the tube can be divided conceptually into an "end" and a "middle" region, while the middle remains empty and all the flux goes to the end. In other words, a one-dimensional model can be applied to the "middle" region.

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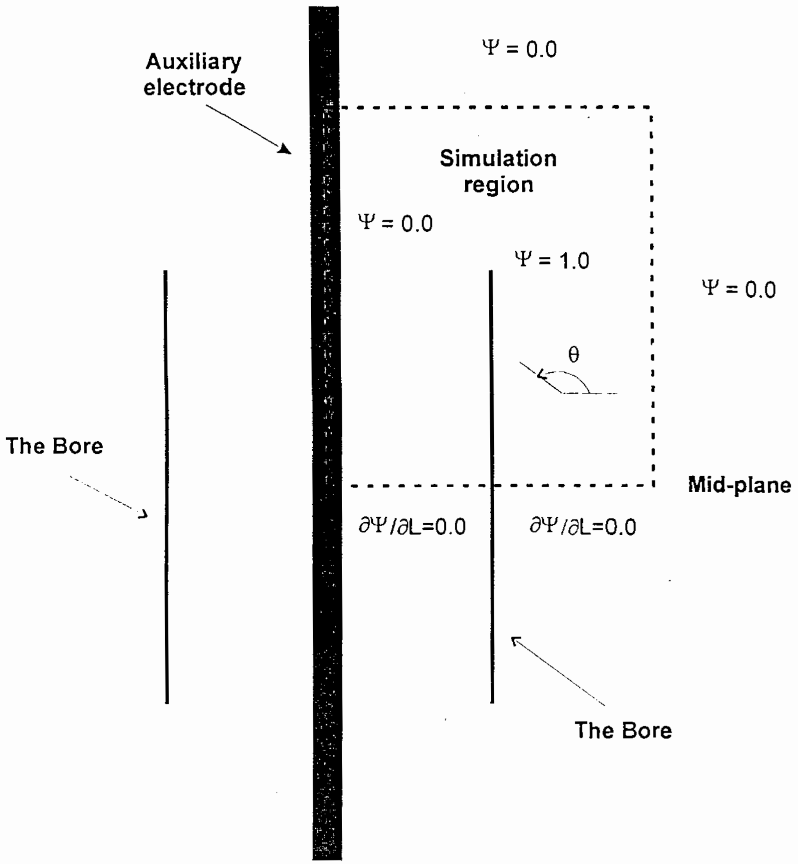

Fig. 1: Schematic diagram of the bore and auxiliary electrode defining the simulation region (demarcated by the dotted lines) and impact angle of the ion.