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Sheath Overlap during Large Scale Plasma Source Ion Implantation*

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We are investigating experimentally the effects of sheath overlap during plasma source ion implantation of a large workpiece of complex geometry. The workpiece consists of 1000 aluminum, automotive piston surrogates mounted on 4 racks; total surface area is over 16 m^{-2}. The 4 racks are positioned parallel to each other, 0.25 m apart, in an 8 m^{-3} vacuum chamber. The racks of pistons are immersed in a capacitive RF plasma, with an argon gas pressure of 0.1-0.6 mtorr. We implant the pistons with the plasma ions by repeatedly pulse biasing the workpiece to -20 kV for 20 μsec. The plasma behavior during the pulse is monitored with a Langmuir probe placed in between 2 racks of pistons. At plasma densities less than 10^{15} m^{-3} and low gas pressures, the sheaths between the racks of pistons overlap, resulting in non-uniform implantation of the plasma ions. In addition, sheath overlap causes a drop in the plasma potential between the racks of pistons. This reduces both the measured ion current to the workpiece and the energy of the implanted ions. At gas pressures of 0.5-0.6 mtorr, we observe the creation of a high density DC discharge in the potential well. The discharge is induced by ionization of the source gas by secondary electrons. While this produces a two order-of-magnitude increase in the measured ion current, the implantation energy is still low. We model the sheath behavior with the two-dimensional, particle-in-cell code XPDP2[1]. Simulations indicate that, at high enough plasma densities, the secondary electrons may heat the plasma through a beam-plasma instability. This results in increased ionization without sheath overlap. Measurements of the plasma evolution as a function of plasma density, gas pressure, and implantation voltage will be presented and compared to simulations. Experiments investigating the use of methane as a source gas are planned; implantation of methane ions prepares the workpiece surface for subsequent deposition of diamond-like-carbon coatings.

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[1]Available from the Plasma Theory and Simulation Group, EECS Dept., University of California in Berkeley.

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Studies of the effects of the bore length during plasma immersion ion implantation of a small cylindrical bore with auxiliary electrode by two-dimensional fluid model

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The inner surface modification of many industrial components, such as dies, bushings, pipes, etc, using plasma immersion ion implantation (PIII) has grabbed the attention of physicists and materials scientists. One drawback of the PIII modification of inner surface is low ion impact energy. It has been shown that by inserting a zero potential conductive auxiliary electrode positioned at the axis of the implanted cylindrical bore, the average ion impact energy can be raised. Plasma immersion ion implantation (PIII) of the inner surface of a finite-length small cylindrical bore with a coaxial, grounded auxiliary electrode are calculated using a two-dimensional fluid model. Various ratios of bore diameters against bore lengths are simulated. It is found that the sheath structure resulting from the auxiliary electrode focuses ions from both inside and outside the bore onto the inner surface. If the bore length is long enough, the ions from outside the bore cannot be implanted into the deeper region of the inner surface. Therefore, we can simulate the implantation of the deeper region by a one-dimensional fluid model.