Metal plasma immersion ion implantation and deposition using polymer substrates

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Abstract

This thesis investigates the application of plasma immersion ion implantation (PIII) to polymers. PIII requires that a high negative potential be applied to the surface of the material while it is immersed in a plasma. This presents a problem for insulating materials such as polymers, since the implanting ions carry charge to the surface, resulting in a charge accumulation that effectively neutralises the applied potential. This causes the plasma sheath at the surface to collapse a short time after the potential is applied.

Measurements of the sheath dynamics, including the collapsing sheath, are performed using an electric probe. The results are compared to theoretical models of the plasma sheath based on the Child-Langmuir law for high voltage sheaths. The theoretical model predicts well the sheath dynamics for conductive substrates. For insulating substrates the model can account for the experimental observations if the secondary electron coefficient is modified, justified on the basis of the poly-energetic nature of the implanting ions.

If a conductive film is applied to the insulator surface the problem of charge accumulation can be avoided without compromising the effectiveness of PIII. The requirement for the film is that it be conductive, yet transparent to the incident ions. Experimental results are presented which confirm the effectiveness of the method. Theoretical estimates of the surface potential show that a film of the order of 5nm thickness can effectively circumvent the charge accumulation problem. Efforts to produce and characterise such a film form the final two chapters of this thesis. The optimal thickness is determined to be near the percolation threshold, where a marked
increase in conductivity occurs. Spectroscopic ellipsometry is shown to be an excellent method to determine the film thickness and percolation threshold non-invasively.

Throughout this work cathodic vacuum arcs are used to deposit thin films and as a source of metal plasmas. The design and construction of a pulsed cathodic vacuum arc forms a significant part of this thesis. Investigations of the cathode spots and power supply requirements are presented.
“When the conjunctions of matter are in your favour a moment
Go and live happily, you did not choose your lot;
Keep company with men of science since your bodily properties
Are a speck of dust joined with a puff of air, a mote with a gasp of breath.”

Omar Khayyam

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Early in this project it became clear to me that there was a lot to learn from a man named John Pigott. With over 40 years experience in the plasma physics department, he is a wealth of knowledge, and I unabashedly stuck to him like glue for a large portion of this project. The construction of the pulsed vacuum arc must be largely attributed to him. His contribution to many other facets of this thesis is also gratefully acknowledged.

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“How long boy will you chatter about the five senses and the four elements?
What matter if the puzzles be one or a hundred thousand?
We are dust, strum the harp boy.
We are air, boy, bring out the wine.”

Omar Khayyam, b.1048-d.1131
Astronomer and Mathematician
Author’s contributions

Chapter 1 is an introductory chapter. Chapter 2 is a review chapter and contains no original results apart from figure 2.1, which was produced by the author using the computer program TRIM, and figure 2.3, which was produced using MATLAB with code written by the author from published theory.

The first half of chapter 3 is a review. The second half contains results from experiments performed by the author. Dr Richard Tarrant provided figure 3.3. An undergraduate student, Paul Thompson, produced the data for figure 3.4, under supervision of the author.

The results presented in chapters 5, 7 and 8 are the work of the author. John Pigott provided the photographs in figure 5.1. Phil Dennis provided figure 5.4. Dr Eungsun Byon produced half of the data in figure 7.5.

Chapters 4 and 6 comprise published work. Contributions by the co-authors are stated on the following page.
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