An Analytical Model of a Multispecies Plasma Immersion Ion Implantation Process in a Collisionless System

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Plasma Immersion Ion Implantation (PIII), has been regarded as one of the most promising and innovative ion-implantation technique in the area of semiconductor device fabrication and material modification. This process technique is a high-dose implantation process technique in the area of microelectronics that has led to various semiconductor applications such as the formation of ultra shallow junctions, synthesis of silicon-on-insulator (SOI) structures, processing of flat panel display materials, trench doping, metallization, etc. In the field of nanotechnology, this fledging technique is an alternative to the conventional line-of-sight ion implantation that overcome many of its limitations like ion source and beam scanning complexity, its high maintenance cost, low beam current, non-uniform implantation profile and low efficiency per implanted ion. It further avoids the intermediate stages of ion source, beam extraction, focusing, scanning while allowing a high dose of ions in a simple, fast, efficient and cost effective manner, eliminating the necessity to mask or manipulate the target.

As a basic mechanism of PIII process technique, the sample is immersed in high-density plasma and is biased with a series of high negative pulses. As a result of negative potential at the sample, electrons near the sample surface are repelled and a uniform sheath of positive ions called Ion-Matrix Sheath is established around the sample, which are then forced to accelerate across the sheath due to the electric field so developed, thereby implanting the ions into the sample surface. Thus the density of ions within the sheath decreases and enough ions are exposed to keep the same sheath potential. This further evolves toward a dynamic sheath called Child-Law Sheath that starts expanding with time thus contributing major part of the doping.

For doping of impurities in semiconductor applications using PIII, the plasma usually consists of compound gases like Phosphine, Borane, etc. which are diluted, in a helium or hydrogen environment for safety considerations. Since no filtering and collimating mechanisms are present in a PIII System, the contaminants indigenous to the plasma as well as undesired ions of these gases can easily co-implanted which may affect the true device characteristics. Thus it is always required that only desired dopants in desired amount are doped for which an exact estimation of doping concentration of individual implant doses is necessary.

For such multiple species plasma, here a generalized and more realistic analytical sheath model in a collisionless regime has been suggested which estimates various parameters like sheath expansion, total implant ion current, total implant dose and the individual ion doses for different species and that too without introducing the concept of effective mass as was suggested by S. Qin et. al.

As an example, combined plasma comprising two singly charged ions of He and Ar has been investigated through this suggested model and ion current components and relative ion dose components for different ion species during a negative pulse of 10KV with 10μs duration have also been computed in this paper.

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