Radical Reaction Based Semiconductor Manufacturing For Very Advanced ULSI Process Integration

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Semiconductor industry is continuously changing from large volume productions with very small variety of semiconductor chips, i.e., personal computer applications, to small volume productions with very wide variety of semiconductor chips, i.e., digital networked consumer electronics applications. Thus, very advanced process integration is essentially required to establish small volume productions with very wide variety of semiconductor chips by introducing radical reaction based semiconductor processings instead of current molecule reaction based semiconductor processings.

Radical reaction based semiconductor manufacturing strictly requires a development of high density plasma equipment with very low electron temperatures less than 1.0 eV and/or ideally speaking 0.7 eV and complete separation between plasma excitation region and process region, where there have been overcome various disadvantages of current plasma equipment such as substrate surface damages and metallic contaminations coming from high energy ion bombardments onto the substrate surface and the process chamber inner surface, charge-up damages and very severe dependence of process uniformity at entire substrate surfaces on substrate surface patterns and materials.

This advanced very low electron temperature high density plasma equipment has been developed by introducing microwave plasma excitation using Radial Line Slot Antenna (RLSA) to very effectively generate various radicals such as oxygen radicals O*, NH* radicals and etc. for surface oxidations, surface nitridations and etc. at low temperatures around 300°C~500°C, where very high integrity SiO_2 and Si_3N_4 films have been obtained to exhibit excellent performances such as very excellent insulator capability improved by a factor of at least three orders of magnitude and very small Flicker (1/f) noise level improved by a factor of at least two orders of magnitude compared to those of current thermal oxide films. Furthermore, radical reactions produce very high integrity SiO_2 and Si_3N_4 film as a gate insulator on any crystal orientation Si surface at low temperatures, while current thermal oxidation at around 1,000°C produces high quality SiO_2 film only on (100) Si surface.

(110) surface Si_3N_4 gate insulator CMOS has been confirmed to exhibit very excellent high speed performance compared to that of current (100) surface SiO_2 gate insulator CMOS by a factor of one order of magnitude. (110) surface Si_3N_4 gate insulator CMOS essentially requires very advanced processings characterized by ultra clean substrate surfaces and ultra clean process environments.

The advanced high density plasma equipment with very low electron temperatures has been implemented to three dimensional (3D) cluster tool having very advanced gas pumping system to establish small volume productions with very wide variety of semiconductor chips, where single process chamber can promote different processes by changing resource process gases, i.e., single chamber/multi-process instead of current single chamber/single process.