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Low-Temperature and Nano-Surface Modification of Materials with Low-Damage Plasma and Photon-Induced Phonon Excitation Processes

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Low-temperature and nano-surface modification and control of materials are required for successful development of next-generation devices including flexible electronics (electronics on polymers) and Si-based MOSFETs for ULSIs. For successful fabrication of electronics on polymers, in which functional electronics devices are fabricated on polymer substrates, it is significant to develop processing technologies which allow low-temperature and low-damage processes to modify nano-surface layer of polymers, since the polymer materials are generally weak against excessive heating and/or damages due to ion bombardment. Furthermore, for fabrication of Si-based MOSFETs for next-generation ULSIs, it is required to develop low-temperature and non-thermal surface modification and control of a variety of materials with nano-structured devices including super-shallow junctions for source/drain extensions and nano-hetero structures for quantum devices and novel channel structures.

To meet these requirements, we have developed low-damage plasma processing technologies with low-inductance antenna (LIA) modules to sustain inductively-coupled RF plasmas and ultra-short-pulse (femto second) laser-induced phonon excitation processes for non-equilibrium (low-temperature) modification of surface nano layers.

The plasmas sustained with LIA modules allow low-voltage high-density plasma production with active control of power deposition profiles over large area, which can be extended to meters-scale large area. Experiments with a meter-scale rectangular reactor resulted in stable source operation to attain high densities > 1E11 cm-3 at gas pressures of ~ 1Pa. Plasma-enhanced CVD of silicon films showed low-temperature (200 deg.C) formation of micro-crystalline silicon films with crystalline fraction > 95 %, which is considered to be attained by sufficiently reduced damage during deposition mainly due to low-voltage operation of ICPs. Ion energy distributions measured with a mass-separated ion energy analyzer showed capabilities of attaining significantly reduced ion energy as low as 3.8 eV.

The ultra-short-pulse (femto second) laser-induced phonon excitation processes provide a novel subsurface modification technique to achieve successful crystallization of nano-scale amorphous layer by adiabatic excitation of phonons. The present approach is based on the concept that the energy required for nano-surface modification is supplied via nonequillibrium adiabatic process rather than via a thermal process.