Low-leakage current and damage-free silicon nitride deposition at 30^{o}C by inductively coupled plasma with neutral beams by neutralization grid plate

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Neutral beams have a great potential for material processes, especially for thin film deposition and etching for fabricating semiconductor devices. Radiation damage caused by charge buildup or ultraviolet and x-ray photons during plasma processing is a serious problem for manufacturing submicron and nanoscale semiconductor devices. However, low-temperature and damage-free processes using neutral beams can overcome these problems. Neutral beam system normally consists of an inductively coupled plasma (ICP) source and a grounded neutralization grid plate at the bottom of ICP chamber. This neutralization plate has numerous apertures for extracting neutral beams from the plasma. Most of ions are converted into neutral atoms, either by neutralization in charge-transfer collisions with gas molecules during ion transport and with the aperture sidewalls in the grid plate, or by recombination with low-energy electrons near the plate.

We present the optical and electrical characterizations of high quality SiN_x films deposited at low-temperature using ICP chemical vapour deposition (ICP-CVD) with neutral beams by a grounded neutralization grid plate. Metal Insulator Metal (MIM) capacitors with 900x120 μm^2 area and 20 nm SiN_x film were realized, which had a breakdown electric field of higher than 4 MV/cm. A leakage current of less than 7 nA/cm^2 at 2 V was observed, indicating high quality film with low pin-hole density, and also less than 7 μA/cm^2 at the breakdown voltage 8.5 V. Comparison with the Si_3N_4 films that were deposited using the conventional ICP-CVD process, which does not have a grounded neutralization grid plate, was also investigated. The conventional ICP-CVD SiN_x film showed breakdown electric field of 4.75 MV/cm, a leakage current about 20 nA/cm^2 at 2 V, and about 40 mA /cm^2 at the breakdown voltage 9.5 V. It is clear that the electrical properties of the SiN_x films deposited by the ICP-CVD with neutral beams are much superior than that of the conventional ICP-CVD SiN_x films.

To further investigate, understand and optimize the neutral beam process, Scanning Auger microscope is used to analyze the chemical compositions of both surface and depth profile of the SiN_x films deposited by different neutral beam processes without exposing the films to air.

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