Plasma Science and Technology
Room 3rd Floor Lobby - Session PS1-TuP

Etching of High-K, Compound Semiconductors and Advanced Materials Poster Session

PS1-TuP1 Influence of Redeposition on the Plasma Etching Dynamics, *L. Stafford,* University of Florida*; **J. Margot**,* Université de Montréal, Canada*; S. Delprat, M. Chaker,* INRS-Energie, Matériaux et Télécommunications, Canada*; S.J. Pearton,* University of Florida

The development of high-resolution pattern transfer processes is one of the critical issues related to the manufacturing of very large scale integrated circuits. As the feature size moves toward the nanometer scale, the commonly used trial/error method for the optimization of dry etching is clearly approaching its limit, and basic understanding of the plasma etching science has become crucial for process control. Basic understanding can be realized for example by developing rate and feature scale models which by comparison of their predictions to experimental data can provide insights into the plasma etching dynamics, and eventually suggest experimental conditions for reliable pattern transfer. In this presentation, we examine the influence of redeposition on the plasma etching dynamics using both experimental and modeling approaches. Redeposition of sputtered species is a common feature in plasma etching and usually leads to the formation of shallow sidewall angles and fences on the sidewall of etched profiles. Even though redeposition is known to play an important role in several plasma etching processes, no quantitative results on the influence of this phenomenon have been reported so far. This work reports on measurements of the redeposition degree during sputter-etching of Platinum (Pt), Barium-Strontium-Titanate (BST), Strontium-Bismuth-Tantalate (SBT), and Photo-Resist (PR) in a high-density argon plasma. While PR exhibits a redeposition-free behaviour, the redeposition degree of Pt, BST, and SBT increases from 10 to 90% as the argon pressure increases from 0.5 to 10 mTorr. The physical mechanisms yielding the observed redeposition effects are discussed. Based on these results and using other experimental data reported in the literature, it is demonstrated that, depending on the plasma etching conditions, redeposition effects can induce misinterpretation of the etch rate data. A rate model taking into account redeposition effects is proposed.

PS1-TuP2 Damage Recovery of (Bi@sub4-x@La@subx@)Ti@sub3@O@sub12@ Thin Films during the Etch Process using Inductively Coupled Plasma Sources, ***J.G. Kim,*** *G.H. Kim, K.T. Kim, C.I. Kim,* Chung-Ang University, Korea

Ferroelectric thin films are employed for ferroelectric random access memories (FeRAMs). FeRAMs offer non-volatility, a lower voltage operation and larger write cycle numbers. (Bi@sub4-x@La@subx@)Ti@sub3@O@sub12@ (BLT) thin films were proposed as a promising ferroelectric material that does not exhibit the polarization fatigue, does have bigger remanent polarization value than that of SrBi@sub2@Ta@sub2@O@sub9@. Moreover, it does not contain the lead contents which occurs environmental disruption. Accordingly, for high density FeRAMs, the etching mechanism of BLT thin films and surface damage during the etching process must be understood. Moreover, damaged films during the etch process should be improved. However, although the etching mechanism was already examined in several researchers, etch damages of BLT thin films and its recovery was not established. In this work, the etch damages of BLT thin films in inductively coupled plasma were investigated with various gas mixing ratios, ICP powers, and bias powers. The etch rates were measured using a surface profiler. For investigating the effects of O@sub2@ plasma, O@sub2@ addition was performed during the etching and etched samples which did not add O@sub2@ gas were treated in the O@sub2@ plasma. After the etching process, the leakage current was measured by parameter analyzer. To evaluate plasma induced physical damages, the changes of lattice of etched BLT samples were evaluated with x-ray diffraction. The precision workstation ferroelectric test apparatus was used for measurement of P-E hysteresis curves. Also the etched surface roughness was evaluated by atomic force microscopy and scanning electron microscope.

PS1-TuP5 Etch Characteristics of Na@sub 0.5@K@sub 0.5@NbO@sub 3@ Thin Films using Cl@sub 2@/BCl@sub 3@/Ar Inductively Coupled Plasma, ***C.M. Kang,*** *K.T. Kim, G.H. Kim, C.I. Kim,* Chung-Ang University, Korea

Recently a unique combination of properties has been discovered in the perovskite Na@sub 0.5@K@sub 0.5@NbO@sub 3@(NKN) thin films. They possess very low loss at room temperature, high piezoelectric coefficient, and moderate dielectric constant, which is strongly dependent on electric field. It was shown that NKN thin films are able to overcome the drawbacks of other materials, such as (Sr,Ba)TiO@sub 3@ and Pb(Zr,Ti)O@sub 3@ for nonvolatile memory applications. Additionally, NKN films exhibit a self-assembly phenomenon despite high volatility of Na and K constituents, strongly c-axis oriented ferroelectric films can grow onto the Si substrates. NKN films are promising for a vast variety of emerging applications, such as nonvolatile memory and actuators. But, etch properties and etching mechanism of NKN have not established yet. In this study, we studied etch characteristics of NKN thin films using inductively coupled plasma for ferroelectric random access memories. The etch rate and etch selectivity in proportion to variations gas mixing ratios, input rf power, dc bias voltage and chamber pressure were obtained. As the ICP power and the rf power increased, the etch rate of NKN also increased. As the gas pressure increased, the etch rate of NKN decreased. The behaviors of active species in plasma were measured by optical emission spectroscopy (OES). Scanning electron microscopy (SEM) was used to investigate the etching profile. X-ray photoelectron spectroscopy (XPS) was carried out to investigate the chemical states of the etched surfaces.

PS1-TuP7 The Etching Characteristics of High-K Dielectric Materials using the Neutral Beam Etching System, ***K.S. Min,*** *B.J Park, C.K. Oh, S.D. Park, J.W. Bae, G.Y. Yeom,* Sungkyunkwan University, Korea

High-k dielectric materials are attractive as a gate dielectric for MOSFETs device because they have wide band gap, superior thermal stability, and low-leakage-current. However, the integration of the high-k dielectric materials is one of the important issues in scaling MOSFET device for the critical dimensions below 50nm. In this study, the etching characteristics of high-k dielectric materials (HfO@sub 2@, Ta@sub 2@O@sub 5@) were studied using a reactive neutral beam. The energetic reactive neutral beam used in this study was formed by reflecting the reactive ions on a planar reflector at a low angle extracted by a reactive ion gun. The etch rate and selectivity between Si and high-k dielectric materials were investigated as a function of reactive gas mixture ratio. Also, the changes in the surface stoichiometry of high-k dielectric materials were measured using an angle resolved X-ray photoelectron spectroscopy (ARXPS) and compared with the surface stoichiometry of the high-k materials etched by inductively coupled plasma etching. ARXPS data showed that the changes in the surface composition of high-k dielectric materials by the neutral beam etching were significantly less compared to those by conventional inductively coupled plasma etching.

PS1-TuP8 Selective Etching of Titanium Nitride, ***D.J. Wu,*** *E.J. Karwacki,* Air Products and Chemicals, Inc.

Titanium nitride (TiN) has many emerging new applications within semiconductor industry. For example, it is already being employed as a metal electrode in DRAM devices, and as a barrier material within logic devices. TiN film can be made using either chemical vapor deposition or atomic layer deposition based processes, where a quartz tube furnace is often used as the deposition reactor. After film deposition, a cleaning process is typically utilized to remove TiN residues. The cleaning process needs to be fast enough to meet the requirements in high volume manufacturing and selective enough to prevent damage to the underlying quartz. Damage such as etching of the quartz will cause surface roughening that may then interfere with heat transfer through the quartz walls to wafers within the reactor. Using a lab reactor with both thermal and remote plasma capabilities, a variety of reactive gases and process conditions were screened for selectively etching TiN. In this paper we report on our development of two thermally assisted processes: a plasmaless process using XeF2 and a remote-plasma process utilizing NF3 in combination with xenon. The XeF2 process provides high etch selectivity for TiN vs quartz at a moderate TiN etch rate. The remote plasma process using NF3 and Xe increases the etch selectivity by an order of magnitude and doubles the etch rate when compared to a NF3 only remote plasma process.

PS1-TuP9 Improvement of External Efficiency using Surface Roughening Technique in the GaN-Based Light Emitting Diodes, ***H.C. Lee,*** *J.B. Park, J.W. Bae, G.Y. Yeom,* Sungkyunkwan University, Korea

Gallium nitride based materials have attracted considerable interest in relation to their potential use in optoelectronic devices, such as light emitting diodes(LEDs) and laser diodes. Recently, as the brightness of GaN-based LEDs has increased, applications such as displays, traffic signals, backlights for cell phones, exterior automotive lighting, and printers have become possible. In general, the internal quantum efficiency for GaN-based

LEDs is far smaller than 100% at room temperature due to the activation of nonradiative defects and it is also well known that the external quantum efficiency is still much smaller than the internal quantum efficiency. The external quantum efficiency of GaN-based LEDs is low because the refractive index of the nitride epitaxial layer differ greatly from that of the air. The refractive indexes of GaN and air are 2.5 and 1.0, respectively. The critical angle for the light generated in active region to escape is about 23degree. Surface roughening of a LEDs is one of the methods for improving the light extraction. Fujii reported an increase in the extraction efficiency of GaN-based light emitting diodes by surface roughening. In this study, we investigated on the improved light output and electrical performance of a GaN-based LEDs by a roughened surface using etching technique. The light output efficiency of a LEDs structure with a roughened surface was significantly increased compared to that of a before roughened LEDs structure. The structural and electrical properties of the surface roughened of the LEDs were evaluated using a scanning electron microscope and a HP4145A probing system. Optical properties such as intensity and wavelength of the emitting-light was observed by an optical emission spectroscopy(OES). Output power of samples was measured by an optical powermeter.

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