temperature. The primary impurity found is oxygen, at levels of the order of 1 atomic %, with hydrogen and carbon atoms also being found at trace levels (i.e., at less than 0.1 atomic %). Deposition parameter optimization is explored, with the aim of producing higher quality films. We also use this molecular beam epitaxy method to fabricate a number of amorphous silicon superlattices, comprised of thin layers of amorphous silicon separated with even thinner layers of SiO_2. The optical properties of the films and superlattices are examined and conclusions are drawn regarding the nature of the disorder and the role of quantum confinement.

A19.2

COMPUTATIONAL MODELING OF HOMOGENEOUS NUCLEATION AND PARTICLE GROWTH DURING CHEMICAL VAPOR DEPOSITION OF SILICON FILMS FROM SILANE PLASMAS. Upendra Bhandarkar, Uwe Kortshagen, Steven Girshick, Dept of Mechanical Engineering, University of Minnesota, Minneapolis, MN.

It is well known that gas-phase nucleation of particles occurs in silane plasmas under certain conditions. This phenomenon is now of interest for the growth of amorphous hydrogenated silicon films with nanometer-sized crystalline inclusions. These films have been shown to exhibit improved medium-range order and enhanced stability against light-induced defect formation. To help understand the process of gas-phase particle formation we have developed a computational model for particle nucleation and growth in capacitively-coupled silane plasmas. This model includes a detailed chemical kinetic mechanism for the growth of silicon hydride clusters. Both plasma chemistry and neutral chemistry are considered. Because anions are trapped in the plasma we include both neutral and anion clusters. The model is zero-dimensional, time-dependent, but species diffusion of neutrals is included in an approximate way as a sink term in the species equations. Electron concentrations are found from plasma quasi-neutrality, and the electron temperature is obtained from the electron energy equation, for an assumed Maxwellian electron energy distribution. The clustering model is coupled to an aerosol dynamics model, that solves for single-particle growth by surface reactions, and for particle charging and coagulation. Results are presented for various operating pressures and power levels, and are compared to experimental observations. The clustering chemistry, particle dynamics, and plasma behavior are found to be strongly coupled to each other. The model predicts the particle charge distribution as a function of particle size. Very small particles are predominantly neutral, whereas for diameters larger than about 10 nm the particles are predominantly negatively charged. A non-negligible fraction of positively charged particles is predicted. This may have important implications for film growth, because positively-charged particles are accelerated into the film by the field across the plasma sheath, whereas neutral particles deposit by Brownian diffusion (and, possibly, thermophoresis), while negatively-charged particles are repelled.

A19.3

EXPANDING THERMAL PLASMA DEPOSITION OF SILICON DIOXIDE-LIKE FILMS FOR MICROELECTRONIC DEVICES. M. Creatore, M.F.A.M. van Hest, M.C.M. van de Sanden, Department of Applied Physics, Eindhoven University of Technology, THE NETHERLANDS.

Silicon dioxide plays a fundamental role in all the devices based on Si technology: it is used as insulator between metal layers in multilevel metal systems, as gate oxide and capacitor dielectric in MOS devices, as mask against diffusion and implantation, as passivator and as sacrificial film in MEMS. The deposited films must exhibit uniform thickness and composition, low chemical contamination and pinhole density, and good adhesion to the substrate. Plasma Enhanced-Chemical Vapour Deposition can successfully meet these requirements, beside allowing low process temperatures. The expanding thermal plasma (ETP) technique, when compared to more conventional plasma systems, leads to a simplified optimisation of the process and facilitates studies of plasma reactions and film growth mechanism, because of the separation between the plasma source and the deposition chamber. The plasma generated in a dc cascaded arc (0.2-0.6 bar) expands through a nozzle into the chamber (0.1-0.3 mbar) where the deposition precursor gases (injected by means of a ring) are dissociated/ionised by the reactive species coming from the arc. The effects of the plasma source parameters (arc current, Ar flow rate), the feed gas composition (hexamethyldisiloxane/oxygen mixture), the substrate temperature and bias (applied to the substrate holder) were investigated. In order to correlate the plasma species density with the deposited film chemistry, a multi-diagnostics approach was carried out. The in situ film growth was monitored by means of Ellipsometry and IR Reflection Absorption Spectroscopy, adapted to our fast deposition process (tenths of nm/s). The plasma phase was investigated by means of Mass Spectrometry and Cavity Ring Down Spectroscopy, used for the determination of the radicals density. The tailoring of the deposition process through the above mentioned diagnostic tools has lead to carbon-free films with very low silanol content (SiOH is primarily responsible for the increase in refractive index and dielectric constant).

A19.4

SURFACE ROUGHNESS EVOLUTION OF PECVD CATHODIC AND ANODIC a-Si:H. George Dalakos, General Electric Corporate Research and Development, Niskayuna, NY; Joel Plawsky, Rensselaer Polytechnic Institute, Dept of Chemical Engineering, Troy, NY; Peter Persans, Rensselaer Polytechnic Institute, Dept of Physics, Troy, NY.

Surface or interface roughness can impact optical, electronic, and MEMS applications of thin a-Si:H films. Deposition at lower temperatures can be advantageous for some applications of a-Si:H, but lower temperature deposition generally leads to rougher films. We have found that the evolution of surface roughness growth can be modified substantially by ion bombardment due to the self-bias of the plasma during Plasma-Enhanced Chemical Vapor Deposition (PECVD). Notable differences in the surface roughness evolution and deposition rate are shown for films deposited in “cathodic” versus “anodic” mode – where the substrate is placed on the powered and grounded electrode respectively. Suppression of surface roughness growth of a-Si:H can be achieved under conditions of relatively high ion bombardment even at deposition temperatures as low as 75°C. Atomic force microscopy (AFM) was used to measure the relative surface roughness profile as a function of deposition time. Analysis of the power spectral density of the roughness yielded important statistical surface parameter information. Based on these observations, insight is given into growth mechanisms under the two deposition conditions.

A19.5

GERMANIUM DAMASCENCE PROCESS BY SELECTIVE LPCVD AND SURFACE SMOOTHENING TECHNIQUE. Chi On Chui, and Krishna C. Saraswat, Stanford University, Dept. of Electrical Engineering, Stanford, CA.

Highly compatible with the silicon-based technology, Ge offers some superior material qualities like higher carrier mobilities and broader absorption spectrum for opto-electronic applications. In addition, the lower processing temperature with Ge makes it an attractive material for post-metallization fabrication of transistors and photodetectors in the upper layers for 3-D ICs. Unfortunately, the water-soluble germanium native oxide rinses off during processing. In this presentation, a damascene scheme for Ge growth by selective LPCVD with LTO (low-temperature SiO_2) barriers is discussed to avoid germanium post-deposition water exposure. On a substrate with both silicon and LTO, pure Ge is deposited by the pyrolysis of GeH_4 in a LPCVD system. Simultaneously, GeH_4 would also etch off native SiO_2 and LTO through a reduction reaction. Since the density of surface adsorption sites, for pyrolysis of GeH_4, on SiO_2 surface is negligibly small compared to silicon, the process of nucleation and growth for Ge film on SiO_2 is more difficult, which explains the selectivity in deposition. However, at some processing conditions, enhanced deposition on SiO_2 can occur. In this study, we try to explain this phenomenon and establish a process window for selective depositions, the corresponding incubation time and the critical Ge film thickness. Contrasting any UHV systems, the finite oxygen contamination in these common LPCVD furnaces would tend to react with the residual GeH_4 gas to form intermediate GeO_x on the Ge surface right after deposition. From both AFM and SEM, hillock structures are observed on the deposited Ge surface, mainly composed of GeO_x as confirmed with EDS analysis. After coating and stripping of photoresist on the surface, almost all the hillocks disappear. The surface RMS roughness also reduces from 35.5nm to 2.8nm, which is similar to the post-CMP polysilicon films for TFT applications.

A19.6

CHARACTERIZATION OF ECR PLASMA USED FOR GROWING AMORPHOUS SILICON, SILICON-GERMANIUM AND SILICON-CARBON ALLOYS. Marsela Pontoh, Vikram Dalal, Neha Gandhi, Iowa State University, Dept. of Electrical and Computer Engr., Ames, IA.

We report on the characterization of ECR plasmas used for depositing a-Si and a-(Si,Ge) alloy films and devices. The plasma was characterized using in situ mass-sectrometery, Langmuir probes and optical emission spectroscopy.The ECR plasma was used in a remote mode, with diluting gases (Hydrogen and Helium) introduced in the plasma zone, and the feedstock gases (silane, germane, methane and ethylene) introduced near the substrate.The substrate coud be biased using a dc voltage source. A grounded grid could be placed in front ofthe substrate, thereby converting the plasma into a triode ECR plasma. It was found that the presence of the grid had a significant influence on the plasma properties reaching the substrate. Without the grid, changing the dc bias on the substrate led to significant