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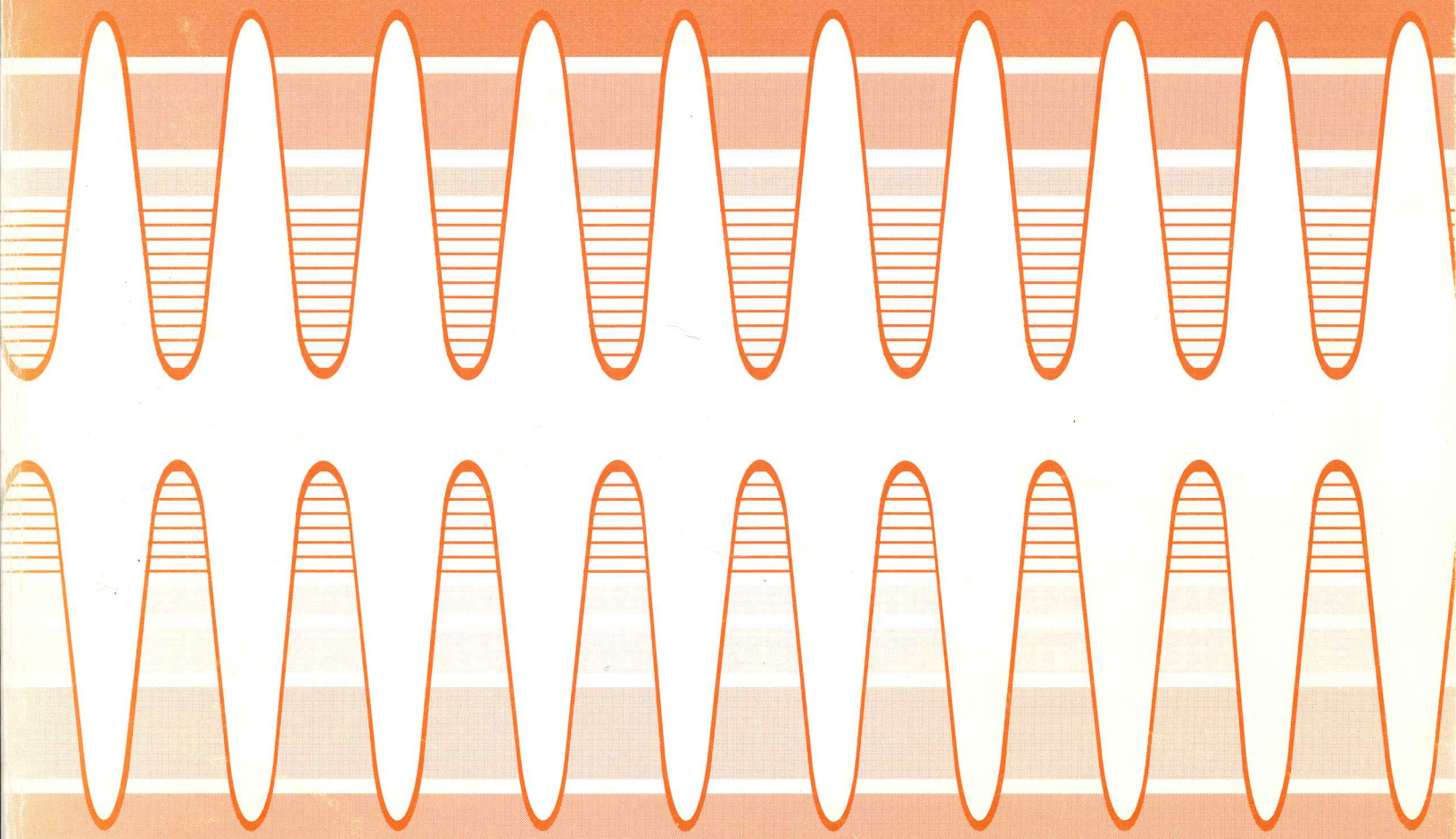

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Technical Program with Abstracts

neering, North Carolina State University, Raleigh, NC 27695-7911.

Atomic layer epitaxy (ALE) of silicon in a CVVD reactor has been investigated using an extraction/exchange process which take place in the dichlorosilane/hydrogen system. Saturation of the growth at one monolayer per ALE cycle was obtained and was found to depend on the exposure times and fluxes of the reactant gases. Low temperature ALE has been achieved using the rotating susceptor reactor approach. The system used for these experiments is designed for low temperature (650-850°C) Si epitaxy. The low water vapor and oxygen levels needed for low temperature growth are obtained by using high purity gases which are further purified with point of use purifiers. The quartz growth tube is similar in design to systems used previously for III-V ALE and has separate inlet tubes for the reactant gases, hydrogen and dichlorosilane (DCS), and an argon shroud. A stationary graphite susceptor is positioned just below the gas inlet tubes where it helps prevent mixing of the DCS and hydrogen. The silicon sample rests on another susceptor positioned just below the first and is rotated by stepper motor to pass the wafer through each gas stream. While rotating, the silicon is exposed to each reactant gas during approximately fifteen percent of each cycle. The ALE experiments have been conducted at low pressure, 50 torr, and most of the research has focused on growth at 825°C.

In the ideal case, the DCS exposure is expected to create one silicon chloride, $SiCl_2$, monolayer on the silicon surface, which does not react readily with DCS and therefore leaves only one layer deposited per exposure. The next step in the process, exposure to hydrogen, results in the formation of gaseous HCl and leaves one silicon monolayer on the surface. Experimental results show that with no hydrogen flowing, though, growth was still observed for all conditions examined. But at 60 rpm, with alternate exposures to DCS and hydrogen, the growth rate increased and a plateau region of one monolayer per cycle was observed for DCS flows ranging from between 5 and 20 sccm. The increase saturated at a moderate hydrogen flow beyond which additional hydrogen has no effect. The deposition per cycle decreases as the rotational speed is increased, and appears to be approaching a constant at high speeds. These data suggest that several pathways may exist for the deposition of silicon using dichlorosilane. Possible pathways include the reaction of the silicon chloride with the hydrogen product resulting from DCS decomposition and the existence of other surface species, such as SiHCl, which do not need hydrogen to decompose. It is therefore possible that kinetically favored reactions may be dominating thermodynamically favored reactions in certain regimes. We present the effects of the growth variables, such as growth temperature (750 to 850°C), exposure times (0,1 to 1 second) and gas flow, on the atomic layer epitaxy of silicon.

9:20 AM, O4 †

Current Transport Properties of Semi-Insulating Oxygen-Doped Silicon Films for Use in High-Speed Photoconductive Switches: P. V. Schwartz, C. W. Liu and J. C. Sturm, Department of Electrical Engineering, Princeton University, Princeton, NJ 08544; T. Gong and P. M. Fauchet, Laboratory for Laser Energetics, University of Rochester, Rochester, NY 14623.

We are investigating current transport properties of CVD grown oxygen doped silicon films for use in high speed photoconductive switches. Two necessary requirements of high speed photoconducting materials are short carrier lifetimes and high carrier mobilities. Two silicon-based materials which show promise for high speed photoconductive applications are oxygen implanted silicon-on-insulator and polycrystalline silicon. These materials have the advantage of silicon compatibility but rely on the material remaining in a non-crystalline phase. This non-crystalline phase is advantageous for short lifetimes but also has the effect of severely lowering carrier mobilities. For example, the electron mobility of poly-silicon is of the order of 10 $cm^2V^{-1}s^{-1}$. In this work, we describe electronic properties of semi-insulating, heavily oxygen-doped, crystalline silicon films, grown by low temperature chemical vapor deposition. Due to the crystalline nature of this material, low lifetimes and high carrier mobilities can be achieved simultaneously.

The oxygen doped silicon was grown epitaxially on (100) silicon substrates in a load-locked rapid thermal chemical vapor deposition reactor. During processing of the oxygen doped films, extreme care was taken to ensure that no contaminants which could limit carrier lifetimes, other than oxygen, were introduced to the growing film. (Typical oxygen concentrations in our "clean" epitaxial silicon films are below the detection limit in Secondary Ion Mass Spectrometry ($<10^{18}cm^{-3}$) and have lifetimes similar to bulk silicon.) Oxygen was introduced to the growth environment in an argon carrier gas through a calibrated mass flow controller. Partial pressures of oxygen were controlled such that oxygen concentrations in the growing films were between 10^{19} and $10^{21}cm^{-3}$. These levels are far above the equilibrium solid solubility limit yet far below the levels introduced in Semi-Insulating Polysilicon (SIPOS)). By growing between 700 and 750°C, high oxygen levels are achieved, yet the films remain generally crystalline in structure. Evidence of the crystallinity comes from X-ray diffraction patterns which exhibit bulk-like silicon peaks with no signs of polycrystalline diffraction peaks and from our ability to grow low-oxygen content, single crystal silicon on top of the semi-insulating oxygen doped layers. Although the exact configuration of the oxygen is not known, Fourier Transform Infrared Spectroscopy does not show characteristics of precipitates or platelets but rather a peak more closely related to that of interstitial oxygen.

The electrical properties of the films were characterized by metal-intrinsic-n, metal-intrinsic-p and p-i-n diodes under forward and reverse bias and by spreading resistance measurements. Resistivity levels, which reach 10^6 ohm-cm at room temperature in the heavily oxygen doped material, demonstrate its semi-insulating nature. In nominally undoped material grown in our reactor, the background carrier concentrations are near $10^{16}cm^{-3}$ n-type, yet in the oxygen doped material, the Fermi level was found to be pinned at midgap due to the trapping levels introduced by the oxygen. The diodes fabricated in this material display the classic characteristics of space charge limited current (SCLC),in a semi-insulating material with trap levels of bandgap ($I\alpha V$ at low applied voltage and $I\alpha V^2$ at higher voltage). Using the model of Lampert and Mark for single carrier injection, the low field, low injection level, electron and hole mobilities are found to be of the order of 100 $cm^2V^{-1}s^{-1}$ with the electron mobility being slightly higher than the hole mobility. This is an improvement of one order of magnitude over poly-silicon and is probably due to the crystalline nature of our material. The double injection devices, which show current controlled negative differential resistance, provide the means for directly comparing the electron and hole capture cross sections of the traps. Finally, we will show the temperature dependence of the trap efficiencies in both the single and double injection devices .

Experiments are currently in progress to determine the carrier lifetimes by means of a pump and probe reflection technique. Preliminary data show that the lifetimes are of the order of ten picoseconds in material with oxygen concentration near $10^{20}cm^{-3}$.

9:40 AM, O5

Deposition and Crystallization of Mixed-Phased Silicon Thin Films: M. K. Hatalis, Department of Electrical Engineering and Computer Science; and A. T. Voutsas, Department of Chemical Engineering, Lehigh University, Bethlehem, PA 18015.

Polycrystalline silicon thin films are finding an important new application in the fabrication of Thin Film Transistors (TFTs) for Active Matrix Liquid Crystal Displays and Static Random Access Memories. We have previously reported that polysilicon ob-