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A Simple Controller for Repetitive Cycles in Atomic Layer Epitaxy

by

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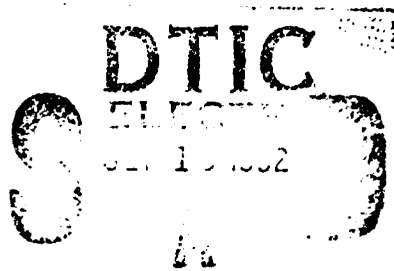

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A simple controller system has been designed and added to an existing deposition system in order to implement deposition of silicon by Atomic Layer Epitaxy (ALE). A Remote Plasma-enhanced Chemical Vapor Deposition (RPCVD) system has been modified for automatic control of repetitive cycles of disilane dosing and hydrogen desorption via low energy ion bombardment. The simple configuration of the input/output modules and ease of programming allowed efficient debugging of the installation and a large degree of flexibility in *in situ* cleaning and in both ALE and CVD experiments.

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A simple controller system has been designed and added to an existing deposition system in order to implement deposition of silicon by Atomic Layer Epitaxy (ALE). A Remote Plasma-enhanced Chemical Vapor Deposition (RPCVD) system has been modified for automatic control of repetitive cycles of disilane dosing and hydrogen desorption via low energy ion bombardment. A commercially available controller made by Tymkon, Integrated Time Systems, was configured for the RPCVD system with 32 digital and 8 analog outputs and 8 digital and 8 analog inputs. The digital outputs drive (Single Pole Double Throw) SPDT relays which are used to switch the output of an external 24 VDC power supply connected to solenoid-actuated valves in the gas lines in order to control the mass flow controllers (MFC's), and to switch the r-f power for the remote plasma in sequential operations. The r-f power supply is enabled via a 5V TTL input which is supplied from a separate external supply. The analog outputs set MFC flow rates of disilane and other silicon precursors as well as germane and the dopant gases, phosphine and diborane. Inputs are used as interlocks to monitor deviation of actual gas flow rates from set point values, valve positions, and condition of the r-f plasma and the DC power supplies. Conditional branching and alarm conditions are programmed as a function of the input channels. The addition of a custom EPROM allows the number of ALE cycles in a process loop to be specified. A typical experiment comprises 100 cycles of disilane dosing and H-desorption, each cycle having 5 steps and lasting 3.5 minutes per cycle. Prior to the start of an ALE experiment, the Si (100) wafer is cleaned *in situ* by a remote H-plasma which leaves a (3x1) H-terminated Si surface. The first step of a typical cycle is the creation of adsorption sites for Si bearing species by desorption of hydrogen from the H-passivated surface. Helium flow is established through the plasma column and the r-f plasma power is enabled to strike the remote plasma. Hydrogen is desorbed by bombardment with low energy He ions resulting in conversion of the (3x1) surface to a (2x1) reconstruction The range of bombardment times studied was 1-4 min. The H-desorption step is followed by Si_2H_6 dosing over a range of partial pressures (10^{-7} Torr to 1.67 mTorr) and times (20 s to 3 min.) without plasma excitation. It is believed that Si_2H_6 chemisorbs on a bare Si surface as 2 silyl(SiH_3) species, re-passivating the surface with H termination. The Si_2H_6 dosing pressures and times corresponded to saturation dosing ($\sim 10^7$ Langmuirs). Following dosing, a 30 s pause was programmed before switching on the plasma and commencing the next cycle to allow for complete depletion of disilane from the system. The temperatures that were investigated were in the range of 250°C-400°C. Installation of a commercially available controller has allowed rapid conversion of an existing deposition system to automatic control. The simple configuration of the input/output modules and ease of programming allowed efficient debugging of the installation and a large degree of flexibility in *in situ* cleaning and in both ALE and CVD experiments.

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