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Si Atomic Layer Epitaxy using Remote Plasma Assisted Hydrogen Desorption and Disilane as a Precursor

by

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13. ABSTRACT (Maximum 200 words)

We have demonstrated silicon Atomic Layer Epitaxy(ALE) using ions from an rf-excited helium plasma glow discharge which held remote from the substrate in a Remote Plasma Enhanced Chemical Vapor Deposition(RPCVD) system to minimize surface damage. The starting surface was a combination of dihydride and monohydride termination. The ALE experiment cycle consisted of bombarding the substrate with He ions from the plasma for 1-3 min. to desorb it followed by dosing the surface with disilane in a range of partial pressures(10^{-7} Torr to 1.67 mTorr), temperatures(250°C-400°C) and times(20 sec to 3 min.) without plasma excitation to adsorb Si_2H_6 on the bare surface Si atoms created by the bombardment as to silyl(SiH_3) species in a self-limiting manner which results in a hydrogen terminated surface. The maximum growth obtained was 0.44 monolayers per cycle for a 3 minute bombardment cycle. The growth per cycle decreases as the bombardment cycle time is decreased, indicating that the percentage of hydrogen removed decreases with the bombardment time.

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Silicon Atomic Layer Epitaxy using Plasma Assisted Hydrogen Desorption and Disilane as a Precursor

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We have demonstrated silicon Atomic Layer Epitaxy(ALE) using ions from an rf-excited helium plasma glow discharge which held remote from the substrate. The *ex situ* clean consisted of a modified RCA clean followed by a brief HF(10:1) dip to obtain a stable hydrogen terminated silicon surface which has been discussed elsewhere. The wafers were then loaded into a Remote Plasma Enhanced Chemical Vapor Deposition(RPCVD) system through a load lock chamber as an efficient way to get a clean fast pumped system. The substrate is held remote from the glow discharge in an RPCVD system to minimize surface damage. The starting surface was a combination of dihydride and monohydride termination, as evidenced by a 3x1 Reflection High Energy Diffraction(RHEED) pattern, which was obtained by an *in situ* H plasma clean which has been described elsewhere. The effectiveness of He and Ar ion bombardment on the surface from a plasma to remove hydrogen from the surface was studied at pressures ranging from 50 mTorr to 400 mTorr, excitation power from 6 to 40W, temperatures from 250°C to 410°C and times from 0.5 to 3 minutes. He ions were found to be more effective for this purpose than Ar ions due to their proximity to H mass than Ar. The RHEED pattern was observed for a change from 3x1 to 2x1 pattern indicating a monohydride coverage or a bare surface. It was found that the most efficient parameters for the ion bombardment were 100 mTorr pressure, 30W plasma power, 400°C temperature, for 1-3 minutes. These parameters were then used in the subsequent ALE experiments. The energy of the bombarding He ions is hypothesized to be in the 40-100 eV range. One ALE experiment cycle consisted of bombarding the substrate with He ions from the plasma for 1-3 min. followed by dosing the surface with disilane in a range of partial pressures(10^{-7} Torr to 1.67 mTorr), temperatures(250°C-400°C) and times(20 sec to 3 min.) without plasma excitation to presumably adsorb Si_2H_6 on the bare surface Si atoms created by the bombardment as to silyl(SiH_3) species in a self-limiting manner which results in a hydrogen terminated surface. The dosing time and pressures were sufficient to ensure saturation dosing($\sim 10^6$ langmuirs). This cycle is then repeated 100 times to get a sufficiently thick film which can be measured with confidence. The maximum growth obtained was 0.44 monolayers per cycle for a 3 minute bombardment cycle. The growth per cycle decreases as the bombardment cycle time is decreased, indicating that the percentage of hydrogen removed decreases with the bombardment time. The maximum growth per cycle observed agrees with the steric hindrance data for disilane and the results obtained by other investigators(Green *et al* using photo-thermal UV-assisted ALE). To show that this growth was not thermal or due to ion bombardment alone control wafers were run. Just dosing for 100 cycles without the ion bombardment for 100 minutes showed that there is no or negligible thermal growth(< 5 Å) under the conditions. Ion bombardment without any dosing for 3x100=300 minutes also showed negligible growth(< 5 Å).