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Silicon Epitaxial Growth by Excited Molecular Beams of Glow-discharge-decomposed Silane

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Silicon thin film crystal was epitaxially grown by excited molecular beams of the chemical species produced in the silane plasma in the glow discharge region. We report the excited molecular beam deposition apparatus and results of SEM and RHEED observations of silicon films grown by the excited molecular beams.

Figure 1 shows a schematic diagram of the apparatus. Source gas (5% SiH_4/Ar) was excited and decomposed by DC glow discharge in the discharge tube. Various chemical species produced in the plasma such as free radicals were introduced through a fine orifice into the growth chamber which was evacuated to high vacuum (~0.01 Pa) so that the mean free path of molecules is longer than the distance between the orifice and the substrate. Charged particles were removed by the deflection electrode so that only the neutral molecular beams reach the substrate. The substrate was a rectangular silicon wafer and was resistively heated.

Film growth hardly occured either in the case without the glow discharge plasma or when the growth chamber was at low vacuum (~1 Pa) where the mean free path is very short and many collisions occur while a molecule travels to substrate. Figure 2 shows surface morphology of the silicon film deposited under the following conditions: the substrate temperature was 660°C, the discharge voltage was 600V, the pressure of the discharge tube was 22Pa and the pressure of the growth chamber was 0.034Pa. Film thickness was about 10μm for 30 minutes growth. RHEED patterns of the silicon films are shown in Fig. 3. For the film depositd at 420°C, the Debye-Sherrer ring and a column structure were observed,

which indicates that the film is polycrystalline. For the films deposited at 550°C and 660°C, clear diffraction patterns for [011] direction of Si(100) surface were observed as well as for the silicon substrate. This means that single crystalline silicon was epitaxially grown over 550°C of substrate temperature by excited molecular beams. These results indicate that active chemical species produced in the silane plasma come upon the substrate as well as source gas molecules, and that these activated molecular species promote epitaxial growth of a silicon film by their high internal energy.

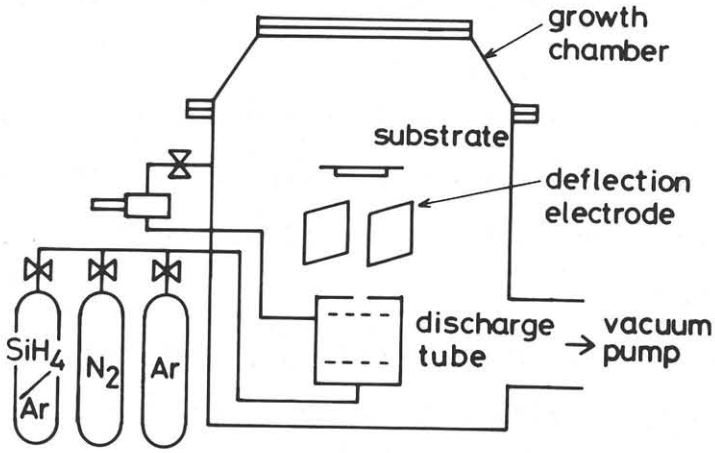

Fig. 1

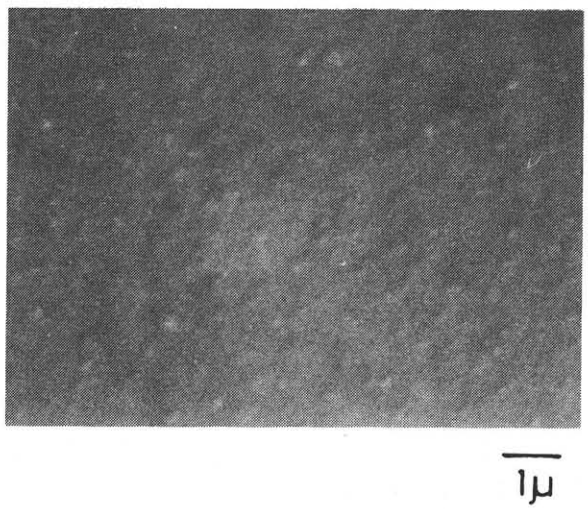

Fig. 2

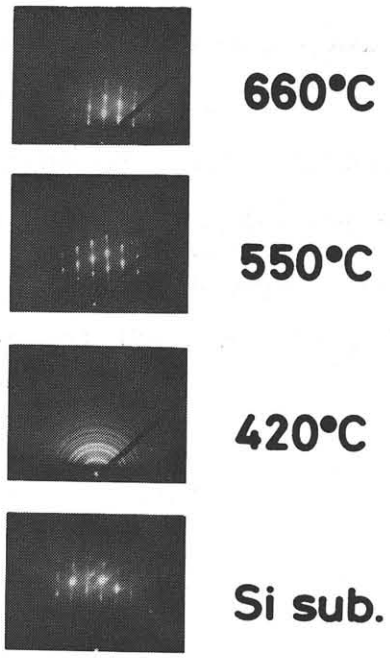

Fig. 3