**Summary of Chapter III: Silicon Dioxide and Silicon Nitride**

**I. Oxidation**

**I.1. Introduction:** Oxidation transforms the surface of silicon wafers into silicon dioxide (SiO₂), a critical process in semiconductor manufacturing. Silicon's ability to form a stable, high-quality oxide layer makes it indispensable for integrated circuit (IC) fabrication, serving as an electrical insulator and providing contamination resistance.

**I.2. Types of Oxidation:**

* **Dry Oxidation:** Involves silicon reacting with molecular oxygen (O₂) at high temperatures, forming a dense and defect-free SiO₂ layer. Reaction: Si(s)+O2(g)→SiO2(s)Si(s) + O\_2(g) \rightarrow SiO\_2(s)Si(s)+O2​(g)→SiO2​(s).
* **Wet Oxidation:** Involves silicon reacting with water vapor (H₂O), which leads to faster oxidation rates but may introduce structural imperfections. Reaction: Si(s)+2H2O(g)→SiO2(s)+2H2(g)Si(s) + 2H\_2O(g) \rightarrow SiO\_2(s) + 2H\_2(g)Si(s)+2H2​O(g)→SiO2​(s)+2H2​(g).

**I.3. Oxide Growth Model:** The Deal-Grove model describes the kinetics of SiO₂ growth, distinguishing between a linear regime (surface reaction-limited) and a parabolic regime (diffusion-limited). The model's key equation is: d2+A⋅d=B(t+τ)d^2 + A \cdot d = B(t + \tau)d2+A⋅d=B(t+τ) Where ddd is the oxide thickness, AAA and BBB are constants related to linear and parabolic growth, and τ\tauτ accounts for initial oxide thickness.

**I.4. Oxide Furnaces:** Thermal oxidation occurs in tube furnaces, divided into zones to ensure uniform temperature and gas distribution. Vertical diffusion furnaces offer improved uniformity for larger wafers.

**I.5. Influence of Chlorine Additives:** Adding chlorine (via HCl or C2HCl3C\_2HCl\_3C2​HCl3​) improves oxide quality by reducing mobile ion contamination, especially sodium ions, which can degrade electrical characteristics.

**I.6. Effects of Crystal Orientation and Pressure:**

* **Crystal Orientation:** Different orientations (e.g., (100) vs. (111)) affect oxidation rates due to varying atomic densities.
* **Pressure:** Higher pressures enhance oxidation rates by increasing oxidant diffusion.

**I.7. Impurities' Impact on Oxide Quality:** Dopants and impurities can accelerate oxidation and affect oxide quality. For instance, heavily doped n-type silicon exhibits faster oxidation due to enhanced diffusivity.

**I.8. Alternative Oxidation Methods:**

* **Chemical Vapor Deposition (CVD):** Deposits SiO₂ without consuming silicon, ideal for interlayer dielectrics.
* **Plasma-Enhanced CVD (PECVD):** Operates at lower temperatures, suitable for temperature-sensitive devices.
* **Low-Temperature Oxidation with Nitric Acid:** Suitable for ultra-thin oxides.
* **Rapid Thermal Oxidation (RTO):** Uses rapid heating/cooling cycles for thin oxide layers.

**II. Silicon Nitride (Si₃N₄)**

**II.1. Properties:**

* **Mechanical Strength:** High hardness and wear resistance.
* **Thermal Properties:** Moderate thermal conductivity and excellent thermal shock resistance.
* **Chemical Resistance:** Resistant to oxidation and corrosion.
* **Optical Properties:** Includes a refractive index varying from 1.8 to 2.5, transparency in the infrared range, and a tunable optical band gap.

**II.2. Deposition Methods:**

* **PECVD:** Uses plasma to enhance reactions between silane (SiH₄) and ammonia (NH₃) at low temperatures. The process allows for good step coverage and uniformity.
* **Hot-Wire CVD (HWCVD):** Utilizes heated tungsten wire to decompose precursors, resulting in high deposition rates and controllable stoichiometry.
* **Sputtering:** Involves bombarding a silicon target with ions, causing silicon atoms to be ejected and react with nitrogen.
* **Laser CVD (LCVD):** Uses laser beams for localized heating, decomposing precursors directly on the substrate for high spatial resolution.

**II.3. Applications in Microelectronics:** Si₃N₄ is crucial in IC fabrication for its insulating properties, passivation capabilities, and role as an etch stop layer. It also serves as a barrier against dopant diffusion.

**II.4. Applications in Photovoltaics:** In solar cells, Si₃N₄ acts as an anti-reflective coating, enhancing light absorption and improving efficiency.

**II.5. Comparison of Deposition Methods:** Each method offers distinct advantages and limitations. PECVD is favored for low-temperature processes, HWCVD for high deposition rates, sputtering for dense films, and LCVD for precise control over film properties.

**II.6. Quality and Structure:** The quality and structural characteristics of Si₃N₄ films vary with the deposition method. PECVD typically yields high-quality, amorphous films, while HWCVD can produce slightly crystalline structures. Sputtering and LCVD offer dense and precise films but may require careful control of impurities and deposition conditions.