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Direct Si-Si Bonding through Self-Assembled Monolayers

Introduction
- Currently, the most widely used bonding method is hydrophilic bonding of oxidized surfaces, which provides high bonding strength. The presence of oxide interface leads to high resistivity and limits the practical applications of bonded wafers.
- Therefore, oxides-free bonding is desired. It can be realized by surface plasma bonding with fast ion beams in a vacuum chamber. However, this bonding method can result in formation of amorphous layer at the bonding interface.
- Direct wafer bonding through **Self-assembled monolayers** (SAM) is anticipated to be an enabling method for oxides-free bonding. Organic monolayers can form spontaneously on surface of substrate by adsorption and passivated the surface from oxidation. After high temperature desorption annealing, the two mating surfaces can bond by covalent bonds.

Theory
- Si radical is formed by extracting hydrogen atoms from a hydrogen-terminated Si surface.
- Si-H will dissociate and Si radical will be formed by thermal activation.
- Then, organic molecules will immobilize on Si covalently through a reaction with Si radical. SAM is formed.

Experimental Procedure
- SAM preparation: Silicon wafers are soaked in beaker containing 0.01M 1-Octadecene in mesitylene at 120 °C for 2 hours.
- Sample rinse: 5 minutes of rinsing with ethanol in ultrasonic bath.
- Bonding: 4 hours desorption time + 5 hours bonding time at 450 °C in vacuum with bonding force of 2.5 kN.

Results & Discussion
- Figure 1: IR image of bonded Si Wafers
- Figure 2: AFM Image of Si Wafer after SAM Implantation (RMS = 0.27 nm)
- Good-quality SAM has been grown and thermal compressive bonding between silicon wafers is successful.
- In future, C-SAM will be performed to examine bonding quality
- Also, 4-point bending test will be done to verify bonding strength.
- Finally, this bonding technique will be applied on other semiconductor materials such as GaAs and InP to achieve the end-goal of combining the best of silicon and non-silicon materials for future chips.

Reference