Plasma assisted low temperature wafer bonding;
void formation in the oxide free interface

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Low temperature wafer bonding is of great interest for bonding of temperature sensitive electronic structures and for hetero-bonded structures. Low temperature wafer bonding can be achieved by using plasma activation [1,2]. This often results in bonded interfaces with thin plasma oxides. For some applications an interfacial oxide is undesirable. Recently a low temperature process for oxide free wafer bonding was presented [3]. Here we investigated plasma assisted low temperature wafer bonding without an interfacial oxide in terms of void formation.

P-type (100) 6” Si wafers were cleaned in SC1 (NH_3(25%):H_2O_2:H_2O 1:4:20) dipped in 2% HF for 20 s and exposed to Ar plasma for 30 s in an ICP RIE, using the ICP mode. Then the wafers were dipped in 2% HF for 40 s and another set of samples were dipped for 270 s. The wafers were rinsed in DI-water, dried and bonded. After two weeks of storage the bonded pairs were sawed and annealed at different temperatures for 6 h in N_2 ambient.

An apparent increase of the surface energy with temperature was observed. For instance, an Ar plasma treated followed by 40 s HF dipped sample possessed a surface energy of 0.6 J/m^2 after annealing at 200°C. This showed the influence of the plasma treatment also after HF dipping.

The samples dipped in HF for 40s showed void formation at room temperature (RT), Fig. 1a. The voids were larger after annealing in 200°C and disappeared at 400°C, Fig. 1b and c, respectively. The samples dipped in HF for 270 s showed no void formation at RT but after annealing at 200°C, 350°C and 400°C, Fig. 2a-d. Fig. e shows that the voids disappeared when annealing for 1 h at 1000°C.

Normally an HF dip of a silicon wafer possesses a hydrophobic behavior and the bonded samples form thermally generated voids [4]. On the contrary, after the final HF dip the surfaces showed hydrophilic character. Since the wafers were treated with HF but still were hydrophilic it is not clear from where the voids originated, but most likely the voids contained H_2 [5]. The different times for the HF dip gave different results concerning void formation. A longer HF dip may have stabilized the plasma treated surface such that voids appeared at higher temperatures than at RT.

References:

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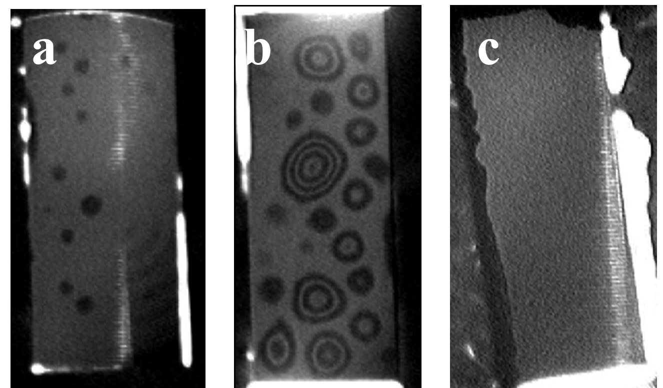

Fig. 1a-c Silicon to silicon bonded samples made by Ar plasma and a 40s HF dip. (a) Voids were formed at RT, (b) after annealing at 200°C and (c) disappeared at 400°C. The annealing time was 6h.

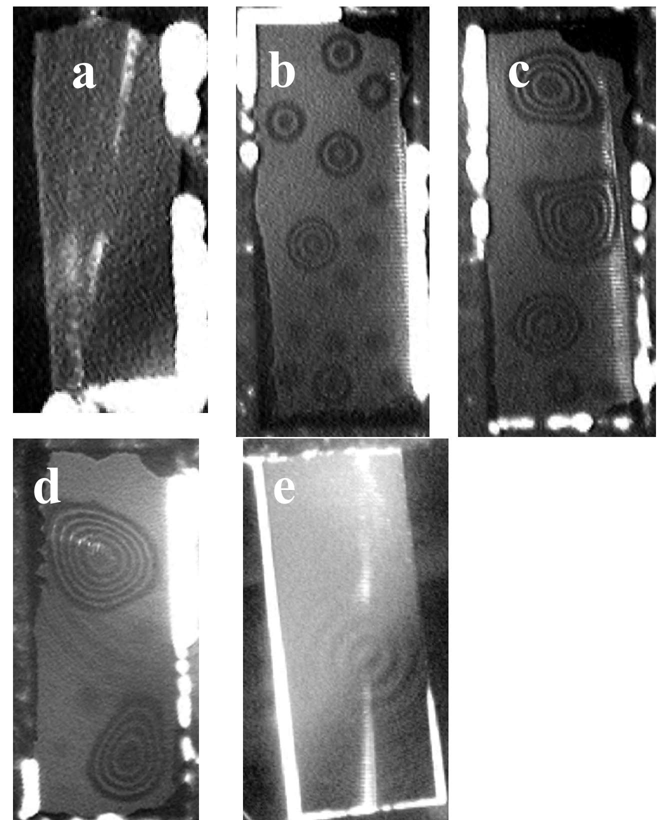

Fig. 2a-e Silicon to silicon bonded samples made by Ar plasma and a 270s HF dip. (a) At RT there were no voids formed, (b) but voids were formed when annealing at 200°C, (c) 350°C and (d) 400°C for 6h. (e) The voids disappeared when annealed at 1000°C for 1h.