

WAFER BONDING USING OXYGEN PLASMA
TREATMENT IN RIE AND ICP RIE

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Results in plasma assisted wafer bonding using a variety of different plasma systems have recently been published. For instance, barrel reactors, reactive ion etchers (RIE) [1, 2] and RIE with inductively coupled plasma (ICPRIE) [3, 4], have been used by different groups. It is of utmost interest to study the influence of the choice of plasma system on the obtained bonding results. Furthermore, understanding the bonding mechanism is of importance to be able to control the bonding step when processing for instance microsystems. Here, results for bonded samples formed by using RIE and ICPRIE are reported.

Four in. p-type (100) oriented float zone wafers were treated with oxygen plasma prior to bonding. In some cases the wafers were cleaned using the RCA1 and RCA2 cleaning before plasma exposure, while in other cases the wafers were taken directly from the box into the plasma chamber. For the plasma exposure in the RIE system a chamber pressure of 40 mTorr, a RF power of 15 W and an exposure time of 30 s were used. In the ICPRIE a chamber pressure of 40 mTorr, a platen power of 15 W, a coil power of 800 W and an exposure time of 30 s were used. Following the plasma exposure the wafers were quickly dipped in de-ionized water, dried and bonded. Both silicon surfaces and silicon dioxide surfaces were used. Also the study contained two types of samples, one where both surfaces were plasma activated (samples A and B in Table I) and the second where only one of the surfaces was plasma activated (samples C-H in Table I). Surface energies were measured 24 h after bonding using the crack opening method. No annealing procedures were used. The measured surface energies are listed in Table I.

Table I. Surface energies obtained 24 h after wafer bonding using oxygen plasma pre-treatment of one or both wafers.

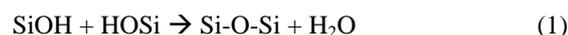
Samples	Surface energy [N/m]	
	RIE	ICPRIE
A Si/Si	1,1	1,6
B SiO ₂ /SiO ₂	1,1	0,5-0,9
C SiO ₂ /Si-no plasma, RCA1+RCA2	debonded	
D Si/Si-no plasma, RCA1	0,7-1,1	
E SiO ₂ /SiO ₂ -no plasma, RCA1	1,1	
F Si/SiO ₂ -no plasma, no cleaning	0,27	
G Si/Si-no plasma, no cleaning	0,8	
H SiO ₂ /SiO ₂ -no plasma, no cleaning	0,45	

An important result is that high surface energies can be obtained using plasma treatment of only one of the wafers (samples D, E and G). This is equally true whether the silicon or the silicon dioxide surface is plasma treated.

The surfaces were left in different states of hydrophilicity after plasma exposure. The samples treated using the ICPRIE procedure always show strong hydrophilic behavior. The samples treated using the RIE procedure

behavior (samples A-C and F-H). In the bonding results when only one of the wafers was plasma treated (samples C-H) there is a tendency of higher surface energies in the case when the plasma treated surfaces showed hydrophilic character. The difference between the wafers showing hydrophilic and hydrophobic character is probably caused by whether they have been exposed to wet chemical cleaning before the plasma treatment (samples D and E) or not (samples C, F-H). The less hydrophilic character observed for some of the wafers treated in the RIE indicate a lower number of adsorbed –OH groups. Our results point out the fact that more –OH groups present on the plasma bonded surface give higher surface energy after 24h when covalent bonds have been formed. Hence the hydroxyl groups have an important role in forming strong covalent bonds at room temperature.

The mechanism of plasma assisted wafer bonding is still under debate. Upon contacting the wafers bond to each other due to hydrogen bonds with water as a contacting media for spontaneous bonding [5]. When water has diffused away the following reaction can take place



The –OH groups are accessible for a reaction only when the water has left the interface. Hence, both diffusion of water from the interface and reaction of –OH molecules are necessary to reach high surface energy. In the case of plasma treatment the –OH groups seem to be mobile enough for reaction. In wet cleaning chemistry the –OH groups are too immobilized to take part in a reaction [6]. Annealing is then necessary.

We speculate that the diffusion of water from the interface is increased due to a porous structure of the plasma treated surface [4]. This can occur even if only one of the surfaces is exposed to plasma. However, the hydroxyl groups at the plasma treated surface seem also to be capable of reacting with the immobilized –OH groups on the surface which has not been plasma treated.

The continuing work is focused on studies aimed at determining if it is water diffusion or the reactivity of the hydroxyl groups that limit the surface energy in plasma assisted wafer bonding.

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