DYNAMICS OF WAFER BONDING

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We have developed a model for the propagation of the bonding front as observed for instance in silicon wafer bonding using IR video camera. The velocity of the bonding wave is used in practice to estimate the bonding strength of a bonding assembly with the idea that a faster bonding velocity corresponds to a stronger adhesion energy. Our aim was to make this statement quantitative through a model and compare the predictions of this model to experimental observations.

The basic assumption underlying the model is that the velocity of the bonding is a (dynamical) balance between a driving force and a resistive force.

The driving force is deriving from the binding energy between the two plates. The resistive force is mainly due to the viscous drag of the air flow between the two wafers. We have calculated the air flow between the two binding plates and derived the viscous dissipation resulting from this flow.

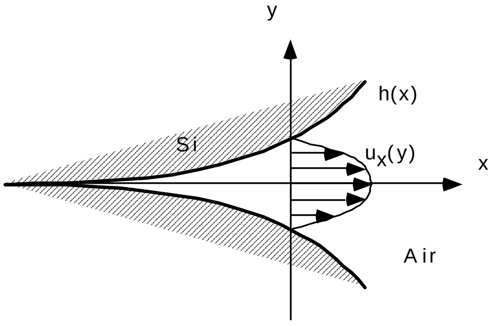

Fig.1: sketch of the deformation with the air flow in between

We then obtain an expression of the binding front velocity U as a function of the binding energy 2γ and the plate deformation profile h(x).

$$U = \frac{2\gamma}{6\eta \int_{x_{min}}^{x_{max}} \frac{dx}{h(x)}}.$$

This expression was compared to experimental measurements where the energy was measured using the blade technique, the velocity through video recording of the bonding front. The profile was obtained from the video images through the observation of interference fringes. Good agreement was obtained when a cut-off equal to the molecular mean free path is taken for the lower limit of the integral in the above equation

Next we have made elasticity theory calculations to derive also the wafer deformation as a function of the pressure distribution established during the air flow between the wafers. This calculation predicts a powerlaw profile with exponent 5/3 for the wafer deformation close to the contact line (see Fig.2).

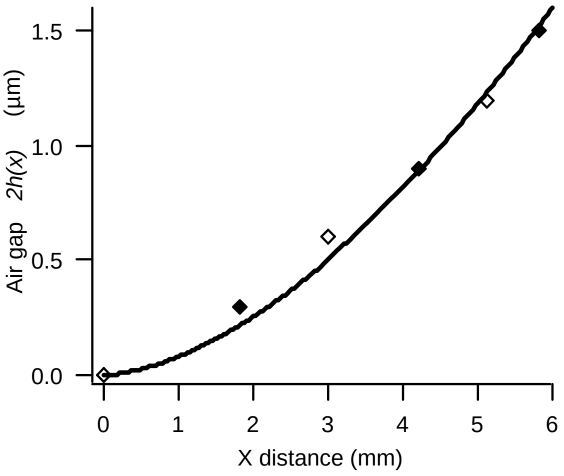

Fig.2 Profile of the air gap during the propagation of the bonding wave. The profile is measured from the interference fringes visible next to the bonding line on video images. The solid line is drawn using our model.

The two equations describing the flow and the wafer deformation under the pressure forces allow one to express the bonding velocity as a function of the different parameters involved in the problem: gas viscosity η, molecular mean free path Λ, elastic constant of the wafer material (Young modulus *E*, Poisson ratio σ), thickness t and binding energy 2γ (*a* is a constant close to 1):

$$U = \frac{(2\gamma)^{5/4}}{\eta\, t^{3/4}} \frac{\Lambda^{1/2}}{(\frac{E}{1-\sigma^2})^{1/4}} (\sqrt{2}/9a^{3/4})$$

This equation was checked against experimental data and literature data [1-3]. The effect of gas pressure, viscosity and wafer thickness can be accounted for using this description. The expression also predicts correct values for the bonding front velocity for the different bonding energy achieved using various surface treatments.

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