THERMODYNAMIC MODEL FOR PLASMA ASSISTED WAFER-BONDING

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Waferbonding is an increasingly important technical process for fabricating advanced semiconductor structures as e.g. tandem or tridem solar cells, MEMS, etc. Within a cooperation between JKU and EVG lasting for more than 10 years, wafer bonding processes for Si, SiO_2, $LiNbO_2$, SiC and other compound semiconductors have been developed[1]. The physics of the interfacial processes is, however, not really well understood and often a multitude of heuristic approaches is tested to achieve a high bond strength at a comparable low temperature. In our contribution we will review published experimental findings and present in addition a general model based the minimization of Gibbs free energy *G*, containing besides the usual thermodynamic quantities also contributions from chemical potential, magnetic energy, electric energy, strain energy, and most important, interface and surface energies (meaning of symbols as usual)

$$dG(T,p,\sigma_{ji},N_k,D,B,A_l,...) = -S(T,p,\sigma_{ji},N_k,D,B,A_l,...)\,dT + V_{liq}(T,p,\sigma_{ji},N_k,D,B,A_l,...)dp_{liq} +$$
$$+V_{solid}\left\{\vec{D}(T,p,\sigma_{ji},N_k,D,B,A_l,...)d\vec{E} + \vec{B}(T,p,\sigma_{ji},N_k,D,B,A_l,...)d\vec{H}) + \varepsilon_{ij}(T,p,\sigma_{ji},N_k,D,B,A_l,...)d\sigma_{ji}\right\} +$$
$$+\sum_{compounds}\mu_k(T,p,\sigma_{ji},N_k,D,B,A_l,...)dN_k + \sum_{\substack{surfaces\ \&\\ interfaces}}\gamma_l(T,p,\sigma_{ji},N_k,D,B,A_l,...)dA_l + ...$$

Certain splitting and bonding steps will be explained and the respective Gibbs energy change will be estimated, for the following cases:
a) splitting of solid materials and the creation of two additional free surfaces,
b) influence of the environment and adsorption processes,
c) the (plasma) activation of the surface or topmost layers,
d) finally the reduction of Gibbs energy when the materials are brought into contact and the activated states decay and thereby form a bond.

In the presentation special emphasis will also be laid on the importance of *metastable states* and *kinetic* processes.

[1] e.g. N. Rauch *et al*., Appl. Phys. Lett. **121**, 081603 (2022)