Surface smoothing process for room temperature wafer bonding
Reduction of local strain at the bonded interface

We found improvement of the bonding strength by surface smoothing effect of the Ne fast atom beam (FAB). Silicon surface roughness decreases from 0.40 to 0.17 nm rms by applying a Ne FAB of 30 nm etching depth. We applied smoothed Si surfaces to surface-activated room-temperature bonding. Without Ne FAB smoothing, bonding between rough Si surfaces cannot be achieved, whereas the bonding energies increase with etching depth up to 5 nm. With Ne FAB smoothing of etching depths over 5 nm, a bonding energy equivalent to that of the bulk materials was finally attained. Local strain at the bonded interface between the rough surfaces was dramatically decreased with the Ne FAB smoothing.

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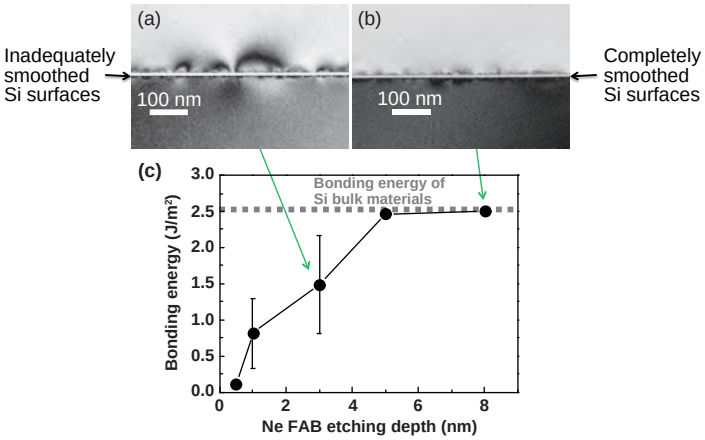

(a)-(b) TEM images of the bonding interface between Si surfaces
(c) Dependence of the bonding energy on the etching depth of the Ne FAB irradiation after Xe FAB roughening

Unraveling a key of high-performance of diamond devices
An important role of atomic-scale structure at diamond surfaces

We have developed a theoretical model that predicts field-emission efficiency of chemically modified diamond surfaces. It was well known that the field-emission efficiency of a hydrogen (H) terminated surface with negative electron affinity (NEA) is higher than that of a clean surface with positive electron affinity (PEA). Thus the polarity of the affinity was believed to govern the emission efficiency, but this is NOT always the case for chemically modified diamond surfaces. We have performed first-principles simulation to monitor electron dynamics under an applied field and compared the emission efficiencies of several chemically-modified diamond surfaces. Co-termination with H atoms and hydroxyl groups (OH) achieves the NEA of the diamond surface, however, our simulation shows lower emission efficiency of this surface compared to the clean surface. It was found that, in addition to the affinity, the detailed profile of potential for electrons along the way from diamond bulk to vacuum through the surface plays a crucial role in determining the performance.

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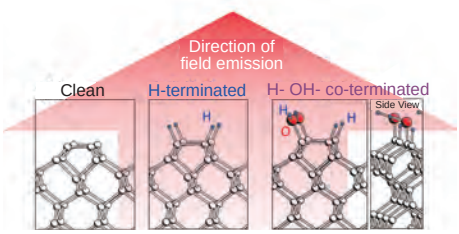
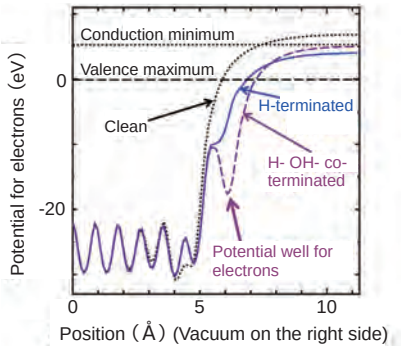


Surface structures of chemically modified diamond surface considered in the simulation



Potential profile for electrons on several surfaces