低温 FIB-断面 STEM 法による Si/Diamond 表面活性化接合界面の構造評価

Structural analysis of SAB-fabricated Si/diamond heterointerfaces by X-STEM and LT-FIB

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Diamond is a promising candidate for a base material of high power electronic devices, as well as for a superior heat spreading substrate, due to its excellent physical properties such as the highest electrical breakdown field strength, the highest thermal conductivity, and a high RF power capability that is 3 times higher in comparison with SiC. For the practical application toward power devices, we need diamond/semiconductor heterointerfaces with high thermal stability and can withstand the temperature rise of power devices during operating. Recently, Liang has demonstrated that diamond/Si [1] heterointerfaces with high thermal stability can be fabricated by surface activated bonding (SAB) at room temperature (RT). In this work, we have examined the bonding mechanism using cross-sectional scanning transmission electron microscopy (X-STEM).

Si/diamond heterointerfaces were fabricated at RT under an optimized SAB condition [1]. A part of the interfaces was annealed at 1000 ºC in a nitrogen gas ambient. X-STEM specimens with an interface were prepared at -150 ºC by using a FIB system (FEI, Helios NanoLab600i) with a cold stage customized for the FIB system (IZUMI-TECH, IZU-TSCS004), so as to suppress the structural and compositional modification due to FIB irradiation [2]. A part of the specimens was annealed at 1000 ºC in a nitrogen gas ambient. Those specimens were examined by high-angle annular dark-field (HAADF), energy dispersive x-ray spectroscopy (EDX) and electron energy loss spectroscopy (EELS) analyses under STEM with a JEOL JEM-ARM200F analytical microscope and with a Thermo Fisher Scientific Tecnai-F20 microscope.

In the SAB process, surfaces of diamond and Si wafers are activated at RT before bonding by creating dangling bonds via the irradiation of high-energy Ar atoms in a high vacuum, and the surfaces are then bonded by the contact most of the time under pressure to form strong chemical bonds even for imperfect surfaces. Atomic intermixing at the interfaces, presumably due to the transient enhanced diffusion assisted by the point defects introduced in the surface activation process [3], is confirmed during the bonding process. The crystallinity at the intermixing region is rather low, and it is recovered by 1000 ºC annealing via the formation of SiC layers, that would play a pivotal role in the relaxation process of the residual stress due to the misfit of thermal expansion coefficient between diamond and Si [1]. Therefore, the defect-assisted atomic diffusion at the interfaces would be a key concept for the formation of high thermal-stability diamond/Si heterointerfaces.

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