Ultra High Precision Of The Tilt/Twist Misorientation Angles In Silicon/Silicon Direct Wafer Bonding.

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New substrates for epitaxy with a nanometric sub-surface patterning are elaborated by direct bonding of ultra thin Si films onto Si wafers. Due to the misorientation of these two single crystals, the direct bonding produces nanometric networks of dislocations localized nearby the bonding interface. In addition to the traditional square network of screw dislocations induced by the twist misorientation, one dimensional mixed dislocation network is generally present due to the tilt disorientation. Indeed, this tilt disorientation is induced by the unavoidable miscut disorientation of the started single crystal wafers (before the bonding). These two classical networks can be seen on figure 1 which is a TEM plane view of a typical silicon/silicon bonded interface. In this case the twist angle is roughly controlled by aligning the flat of the two wafers. The screw dislocation network perturbed by the mixed dislocation network is obtained with a twist disorientation of 2.75°±0.1° (3° targeted) and a tilt disorientation of 0.34°±0.03° respectively.

An original direct wafer bonding process has been developed to accurately control both the bonding interface twist and tilt angles between the two bonded single crystals. This process is based on the bonding of “twin” surfaces coming from a single wafer, using for instance the Smart Cut® process. The twist angle is achieved with an accuracy of about ±0.005° without any alignment measurement based on diffraction techniques, but only by positioning lithographic marks. Using such process, pure twist-bonded interfaces have been made between two (001) bonded silicon surfaces. Pure square dislocation networks are so obtained at the bonding interfaces. In figure 2, TEM observation shows the excellent regularity of such network without the traditional mixed dislocations. In this example, the targeted twist angle was 0.44° to separate the screw dislocations by 50nm. The measured average period of the screw dislocation network (=50±0.1nm) gives a twist angle of 0.435°±0.005°. The absence of mixed dislocation indicates a tilt angle below 0.01°. Grazing incidence X-Ray diffraction also confirms the very good precision of the bonding alignment and the regularity of the network over several square millimeter.

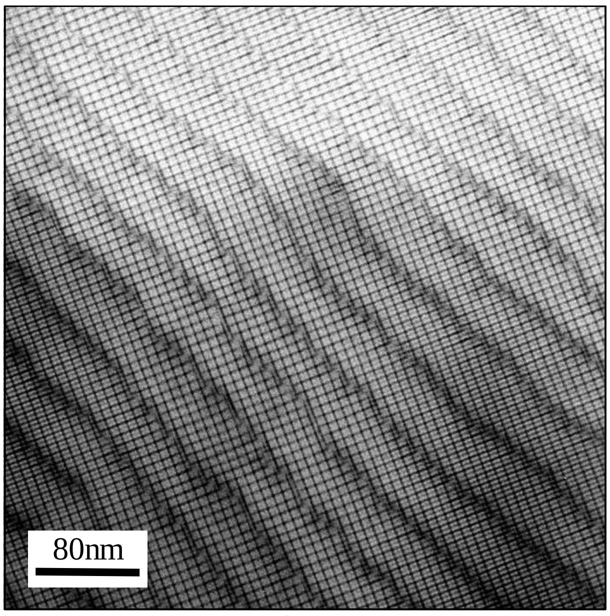

Fig. 1. TEM plane view of a typical silicon/silicon bonded interface. In that case the twist angle is roughly controlled by aligning the flat of the two wafers. A 2D network of screw dislocations perturbed by a 1D network of mixed dislocations is obtained with a twist disorientation of 2.75°±0.1° (3° targeted) and a tilt disorientation of 0.34°±0.03° respectively.

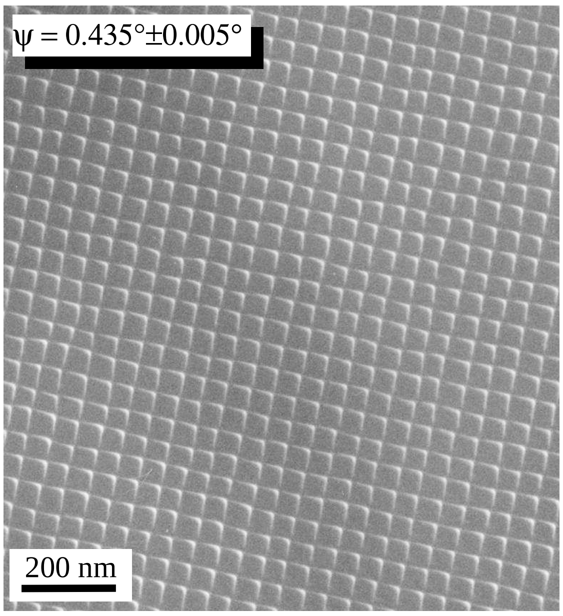

Fig. 2. Large area TEM plane view of a pure twist grain boundary fabricated by wafer bonding with angular control. The targeted twist angle was 0.44° to separate the screw dislocations by 50nm. The average period of the screw dislocation network (=50±0.1nm) gives a twist angle of 0.435°±0.005°. The absence of mixed dislocation indicates a tilt angle below 0.01°.

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