Supporting Information

Transferrable single crystalline 4H-SiC nanomembranes

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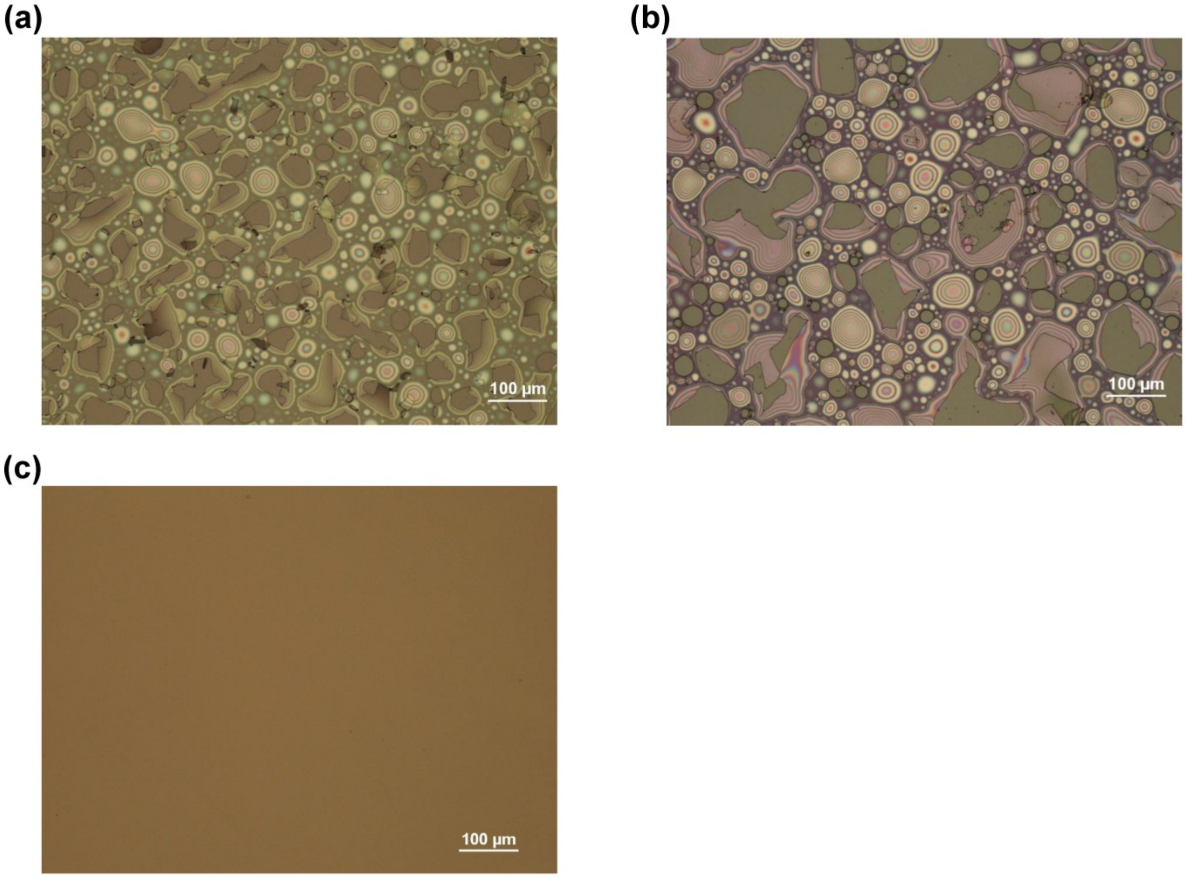

Fig. S1 (a) A microscopic image of surface of the SiC wafer after being annealed at 850℃ **(b)** at 950℃. **(c)** at 1050℃.

Fig. S1 shows the microscopic images of the SiC wafer after being annealed at (a) 850, (b) 950, and (c) 1050℃. SiC flakes with an average size of 50 μm were exfoliated from the SiC wafer annealed at 850℃, while the majority of other SiC areas was not exfoliated with visible blisters inside the SiC. The size of the exfoliated SiC flakes from the SiC wafer annealed at 950℃ was larger relative to that of the SiC wafer annealed at 850 ℃. However, the exfoliation of the continuous SiC layer was still not obtained from the SiC wafer due to the high activation energy of microcrack formation for the SiC (i.e., 4.0 eV).[1] Temperatures used for splitting the SiC (i.e., 850 and 950 ℃) initiated the formation of the flakes, but internal pressure required for the continuous microcrack was not achieved. The continuous SiC layer was successfully exfoliated from the bulk SiC wafer annealed at 1050 ℃. No SiC flakes and blisters can be found from the surface. The 800 nm thick SiC layer was transferred onto the SiO_2/Si handling wafer without any visible voids. It was found that 1050 ℃ was the minimum temperature required for complete exfoliation of the SiC with an annealing time of 8 hours.

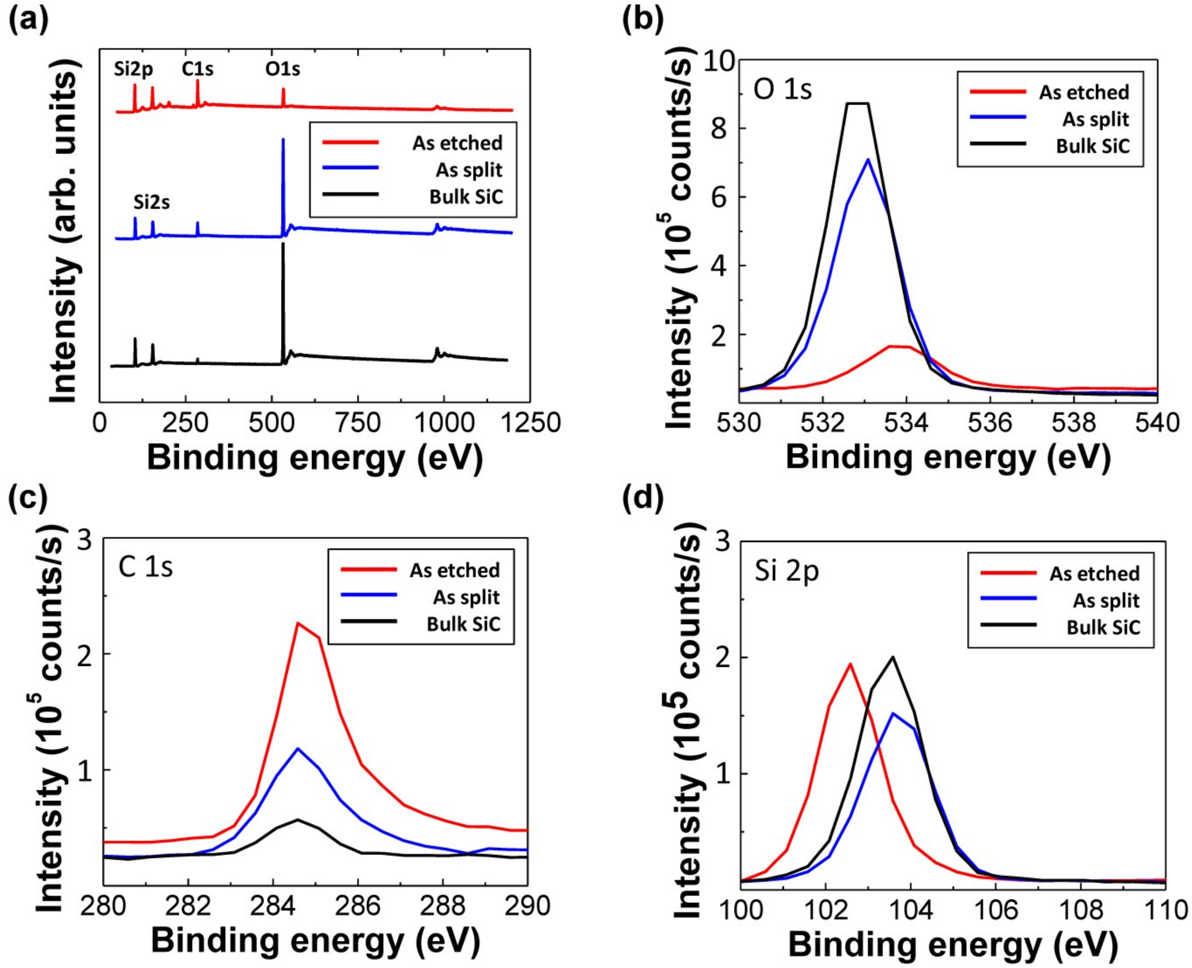

Fig. S2 (a) X-ray photoelectron spectroscopy (XPS) spectra of the as-etched SiC, as-split SiC layer of the SiCOI wafer, and bulk SiC wafer. **(b)** The XPS spectra of the O1s photoelectron peak. **(c)** The XPS spectra of the C1s photoelectron peak. **(d)** The XPS spectra of the Si2p photoelectron peak.

XPS was carried out to evaluate the effect of the ICP-RIE etching on the surface of the SiC layer. The measurement was performed on (1) the untreated bulk SiC, (2) as-split, and (3) as-etched SiC layer of the SiCOI wafer using a micro-focused monochromatic Al Ka X-ray source. No additional surface treatment on SiC was performed prior to the measurement. Fig. S2 shows a comparison of a typical XPS spectrum with zoomed-in focus on O1s, C1s, and Si2p core peaks, respectively. The intensity of the O1s core peak from the as-etched SiC was significantly reduced. However, the intensity difference between the bulk SiC and as-split SiC was small (Fig. S2(b)). This indicates that a native oxide was effectively removed from the SiC surface by the ICP-RIE. The O1s peak position of the as-etched SiC was shifted to a higher binding energy by 0.5 eV compared to that of the bulk and as-split SiC. It shows that the remaining oxide in the as-etched SiC became slightly fluorinated because the binding energy of O1s with chemical state for O-F_x is at ~535 eV. [2,3] The C1s core peaks were measured at 284.8 eV with no measureable peak shift, while the intensities increased as the SiC was processed from the bulk to the as-split and as-etched SiC. Chemical states of the C1s spectrum for contamination are C-C, C-O-C, and O-C=O, respectively. Among them, as shown in Fig. S2(c), the stronger C-C binding energy of 284.8 eV suggests that the etched SiC surface suffers from adventitious carbon contamination originated from the etching chamber.[4] The Si2p core peaks for the bulk and as-split SiC were measured at 103.6 eV. The Si2p core peak position of the as-etched SiC was shifted to a lower binding energy by 1 eV compared to that of the bulk and as-split SiC. This shift could be due to reduced oxide on the as-etched SiC. Si in the oxide is in the 4+ valence state, whereas Si in the SiC is in a charge neutral oxidation state originated from the covalent bond of the SiC. Less screening by valence electrons from thicker oxide could result in a higher binding energy of the Si2p core peak.[5]

Reference:

1. Q.-Y. Tong, K. Gutjahr, S. Hopfe, U. Gosele, and T.-H. Lee, Appl. Phys. Lett.,1997, **70**, 1390.

2. T. Xiao, W. Cui, M. Cai, R. Liu, J. W. Anderegg, J. Shinar, R. Shinar, J. Photon. Energy., 2012, **2(1)**, 021006.

3. See http://xpssimplified.com/elements/oxygen.php, for XPS interpretation of oxygen.

4. See http://xpssimplified.com/elements/carbon.php, for XPS interpretation of carbon.

5. G. G. Jernigan, R. E. Stahlbush, and N. S. Saks, Appl. Phys. Lett., 2000, **77**, 1437.