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Transfer of 2D Materials Using Smart Cut™

Graphene is a promising candidate for the next-generation electronics and optoelectronics as it offers charge carrier mobility over 10,000 cm^2/Vs, high saturation velocity and high thermal conductivity. Apart from graphene, there is a variety of other two-dimensional (2D) materials, such as transition metal dichalcogenides, that offer unique electronic and optoelectronic properties in combination with ultimately thin, two-dimentional nature. Recent progress in the synthesis techniques has made the cost-effective wafer-scale production of 2D materials possible. However, the direct growth of these materials on a dielectric substrate remains challenging. That is why a reliable and scalable technique for transfer of 2D materials from the growth substrate becomes a key technological step. The existing methods of transfer are unreliable or have severe disadvantages. Direct mechanical delamination leads to rupture of the 2D layer. Polymer-based methods of transfer, as well as chemical etching of the growth substrate, lead to deterioration of 2D material properties due to contamination and uncontrolled doping. Besides, implementation of such methods on the large industrial scale is improbable due to their low reliability.

Wafer-scale transfer of thin layers of materials is commonly used on the semiconductor-on-insulator (SOI) industry. Smart Cut™ is one of the most advanced technologies for such transfer and it was developed at CEA. It is based on the implantation of gas ions inside a target substrate with a well-defined implantation depth. As a result, a nm-thick layer of crystalline material can delaminate from the rest of the wafer and get transferred to another wafer (typically SiO_2/Si) via direct wafer bonding. Numerous studies have optimized each step of this process for a wide range of materials, such as Si, SiC, Ge, etc.

The objective of this project was to develop a novel method of wafer-scale transfer of 2D materials - such as graphene and TMDCs - to a target dielectric substrate (SiO_2/Si wafer). The proposed technique is based on the Smart Cut™ technique conventionally used for the transfer of ultrathin layers of silicon, and paves the way for monolithic integration of graphene and other 2D materials with Si-based electronics. Successful implementation of this technique required a thorough investigation of surface interaction of the transferred layer with the donor and target substrates using Raman spectroscopy, AFM, SEM and TEM studies presented in this report.

Figures

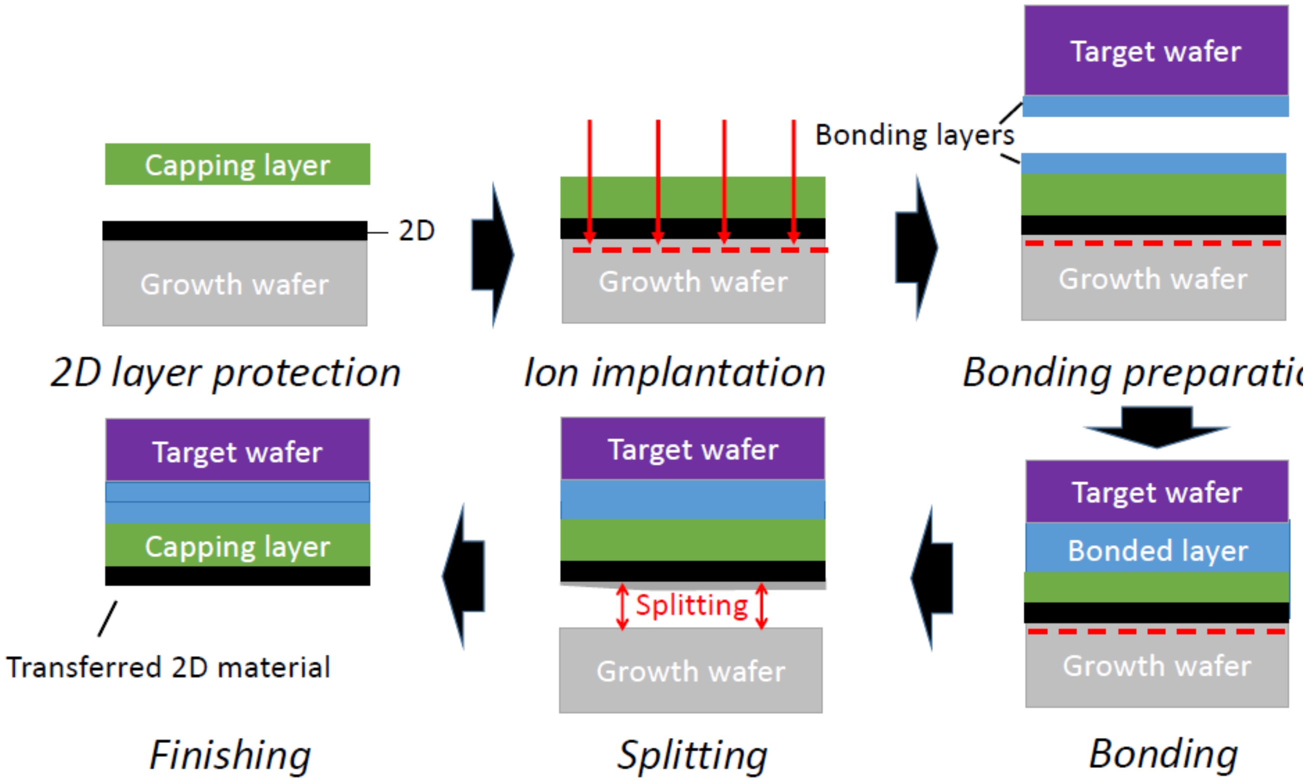

Figure 1: Graphic representation of wafer-scale 2D material transfer using Smart Cut ™