Laser-Induced Structuring of SiC Wafers and Epitaxial Graphene Growth: Towards Hybrid SiC/graphene MEMS for Extreme Environments

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Abstract: Microelectromechanical systems (MEMS) are widely used as sensors and actuators across various industries because of their excellent performance and low cost. However, silicon-based MEMS exhibits limitations in extreme environments due to lack of material stability. Silicon carbide (SiC), with its wide bandgap and exceptional physical and chemical robustness, offers an ideal alternative for MEMS applications in harsh conditions. In this study, we developed a laser-based process for fabricating structures on SiC wafers and explored a method for localized growth of epitaxial graphene within laser-affected zones (LAZ). Through 1030-nm femtosecond laser irradiation, we successfully fabricated various structures on 6H-SiC wafers, with LAZs formed around the ablated regions. The morphology and chemical composition of the LAZs were characterized using optical microscopy (OM), scanning electron microscopy (SEM), atomic force microscopy (AFM), profilometry, and X-ray photoelectron spectroscopy (XPS). Our results indicated that the formation of LAZs was driven by oxygen penetration and SiC oxidation during laser treatment. To improve surface quality after laser irradiation, the LAZs and residues from irradiation were effectively removed using mixed acid solutions. Additionally, laser processing facilitated the growth of epitaxial graphene within the LAZs through thermal treatment of the SiC wafers. This study provides a straightforward, mask-free approach to SiC wafer structuring through laser and acid treatments, and offers critical insights into the impact of laser processing on structural and chemical properties of SiC wafers. These findings establish a foundation for the future development of hybrid SiC/graphene MEMS structures, which could be essential in applications designed for extreme environments.