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Cyclic Etching Process Using Inductively Coupled Plasma for Polycrystalline Diamond on AlGaN/GaN Heterostructure

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Abstract : Gallium nitride (GaN) is an attractive material for next-generation power devices. It is noted that the performance of GaN-based high electron mobility transistors (HEMTs) is always limited by the self-heating effect. In response to the problem, integrating devices with polycrystalline diamond (PCD) has been demonstrated to be an efficient way to alleviate the self-heating issue of the GaN-based HEMTs. Among all the heat-spreading schemes, using PCD to cap the epitaxial layer before the HEMTs process is one of the most effective schemes. Now, the mainstream method of fabricating the PCD-capped HEMTs is to deposit the diamond heat-spreading layer on the AlGaN surface, which is covered by a thin nucleation dielectric/passivation layer. To achieve the pattern etching of the diamond heat spreader and device preparation, we selected SiN as the hard mask for diamond etching, which was deposited by plasma-enhanced chemical vapor deposition (PECVD). The conventional diamond etching method first uses F-based etching to remove the SiN from the special window region, followed by using O_2/Ar plasma to etch the diamond. However, the results of the scanning electron microscope (SEM) and focused ion beam microscopy (FIB) show that there are lots of diamond pillars on the etched diamond surface. Through our study, we found that it was caused by the high roughness of the diamond surface and the existence of the overlap between the diamond grains, which makes the etching of the SiN hard mask insufficient and leaves micro-masks on the diamond surface. Thus, a cyclic etching method was proposed to solve the problem of the residual SiN, which was left in the F-based etching. We used F-based etching during the first step to remove the SiN hard mask in the specific region; then, the O_2/Ar plasma was introduced to etch the diamond in the corresponding region. These two etching steps were set as one cycle. After the first cycle, we further used cyclic etching to clear the pillars, in which the F-based etching was used to remove the residual SiN, and then the O_2/Ar plasma was used to etch the diamond. Whether to take the next cyclic etching depends on whether there are still SiN micro-masks left. By using this method, we eventually achieved the self-terminated etching of the diamond and the smooth surface after the etching. These results demonstrate that the cyclic etching method can be successfully applied to the integrated preparation of polycrystalline diamond thin films and GaN HEMTs.

Keywords : AlGaN/GaN heterojunction, O_2/Ar plasma, cyclic etching, polycrystalline diamond
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