Plasma Assisted Bonding of Diamond and SiC for Power Electronics

Yonhua Tzeng[1,2], Cheng-Ying Jhan[1], Pin-Sen Wang[1], and Yu-Lun Chang
[1]*Institute of Microelectronics, College of EECS, National Cheng Kung University, One University Rd, Tainan, Taiwan*
[2]*Academy of Innovative Semiconductor and Sustainable Manufacturing, National Cheng Kung University, One University Rd, Tainan, Taiwan*
tzengyo@mail.ncku.edu.tw

SiC is an important wide-bandgap semiconductor for the fabrication of high-voltage and high-power electronic devices such as field –effect transistors. Commercially available SiC wafers are of larger and larger diameters year after year. SiC is therefore used for heteroepitaxial growth of GaN for the fabrication of medium-high-voltage and high-power transistors. Although the thermal conductivity of SiC is only about 1/6 of that of crystalline diamond, it is several times better than GaN, which suffers from severe challenges in dissipating heat being generated during switching of GaN transistors. It is therefore desirable to reduce the thickness of a SiC substrate and replace it with diamond. Diamond can be chemically vapor deposited on SiC or bonded to SiC to serve as a heat spreader. CVD of a thick diamond film on SiC is possible but takes long time even at high temperature. Therefore, bonding of single crystal diamond to SiC becomes a promising approach to enhancing the output power of GaN and SiC devices while keeping the device temperature under an acceptable level. With recent progresses in growing crystalline diamond heteroepitaxially, large-area diamond with high thermal conductivity is expected to become available and affordable to serve as a heat spreader for high-power devices and circuits made on large-diameter wafers if a bonding process between diamond and SiC and/or GaN produces a low interfacial thermal barrier with the strong bond being durable and compatible to working environments.

We are devoted to the search for promising strategies and methods of bonding diamond with SiC. GaN devices are fabricated on GaN epitaxial layers grown on SiC substrates. Most of a SiC substrate is removed to reduce the thermal resistance due to SiC. Atomic diffusion bonding is applied to form an electrically conductive or insulating interface between diamond and SiC. Performance of GaN on SiC is compared with that on SiC/diamond. In-situ plasma treatment of bonding surfaces helps removing undesirable contaminants and reaction products for improved bonding outcome. In this paper, we will report progresses made and challenges still being faced in our efforts towards achieving high-thermal conductivity wide-bandgap hybrid power devices and circuits.