Development and perspectives of Ga_2O_3 epitaxial layers for power electronics

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Ultrawide bandgap (UWBG) semiconductors such as gallium oxide (Ga_2O_3) have gained considerable attention and attracted interest for applications in power devices, optoelectronics, and high-temperature sensors. Ga_2O_3 exhibits five polymorphs: α (rhombohedral), β (monoclinic), γ (defective spinel), δ (cubic), and k (orthorhombic). The monoclinic β-Ga_2O_3 is the only thermodynamically stable while other polymorphs tend to convert to β at high temperatures. Ga_2O_3 has an ultra-wide band gap around 4.8 eV, a theoretical electron mobility of about 200 $cm^2\ V^{-1}\ s^{-1}$, an estimated breakdown field over 6 $MVcm^{-1}$. Therefore, Ga_2O_3 is considered a very promising material for high voltage power-switching and next-generation power devices, as well as for fabrication of solar-blind detectors for UV-C radiation. A major advantage of β-Ga_2O_3 over the established GaN and SiC is given by the possibility of growing single crystals from the melt, thus providing large size substrates for epitaxy. Floating zone, Czochralski (CZ), vertical Bridgman, and Edge-defined Film-fed Growth (EFG) were successfully applied to growth of bulk Ga_2O_3, although so far only CZ and EFG were applied to production of substrates. At present, both n-type and semi-insulating β-Ga_2O_3 wafers are commercially available, usually doped with Sn and Fe.

The availability of conductive Ga_2O_3 substrates makes homoepitaxy and fabrication of both planar and vertical electronic devices possible, with the vertical structure preferred for power devices. Epitaxial growth is obtained by different techniques: pulsed laser deposition (PLD) molecular beam epitaxy (MBE), magnetron sputtering, halide vapor-phase epitaxy (HVPE), metal-organic chemical vapor deposition (MOCVD), and mist-CVD, which allowed to cover the entire range of Ga_2O_3 polymorphs. Research has mainly been directed to improving the epilayer structural perfection and doping efficiency, as well to increasing the growth rates. This included growing layers on hetero-substrates and misoriented homo-substrates to get step-flow growth and lower defect density. The addition of In and Al to the binary Ga-O system results in lower and higher bandgap, respectively, than Ga_2O_3, which brings about unprecedented physical properties and applications.

In this presentation, the recent advancements in chemical vapor deposition of epilayers of different phases of Ga_2O_3 will be discussed, along with some examples of diodes and transistors for high-voltage and power applications.

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