Gallium oxide: An emerging device technology

Promises, status and challenges

Gallium oxide (Ga_2O_3) is an ultra-wide band gap (~4.8 eV) semiconductor which is at the heart of a fast-expanding materials and device community. Research activities on understanding and developing various aspects of this technology have been gaining an exponential momentum around the world in the last few years for the promises it holds in electronics and optoelectronics.

With a breakdown field that is demonstrated to be much higher than the theoretically achievable maximum limit of gallium nitride (GaN) which is its rival but more-matured wide band gap technology, Ga_2O_3 is poised to be a leading contender for enabling next-generation power electronic transistors. In the growing market of e-vehicles, on-board chargers, miniature laptop adapters, solar inverters and a host of other applications requiring power conversion, the importance of efficient, compact and high-performance power transistors cannot be over emphasized. In this context, Ga_2O_3 stands out as an attractive candidate to enable applications which might not be viable with other contemporary device technologies. Besides, alloys of Ga_2O_3 span a wider range of deep-UV wavelengths compared to other wide band gap materials which is immensely promising for a plethora of applications requiring solar blind detection. One of the key advantages Ga_2O_3 enjoys is its probable economic edge: it can be grown from the melt, and thus large-area single crystal substrates can be grown which are already commercially available.

In this tutorial, we shall introduce Ga_2O_3 as an emerging ultra-wide band gap semiconductor and put in perspective where it stands vis-à-vis its promises and superiority over its rival and contemporary device technologies. The basic material properties, its polyphases and the various methods of depositing or growing Ga_2O_3 will be highlighted. Next, the status and promises of Ga_2O_3-based transistors for beyond-GaN high-power applications will be discussed. This will include a review of various types of transistors (such as lateral and vertical geometries) reported across the world, and their performance as benchmarked against the more-mature GaN-based devices. Alloys of Ga_2O_3 and their heterostructures for modulation doped FETs will be elaborated upon. Next, the status and developments in the area of Ga_2O_3-based deep-UV detectors will be discussed. Various detector architectures and their state-of-art performances will be touched upon with a comparison with those of III-nitride and commercial silicon UV detectors. The possibilities of multi-spectral and broadband UV detection by exploiting the wide range of band gaps of Ga_2O_3-based alloys and their heterojunctions with III-nitrides will be highlighted.

However, Ga_2O_3 has certain limitations and challenges, and one of them is the absence of p-type doping. Low electron mobility is another cause of concern for high-power devices. Thus, in the conclusion of this tutorial, the challenges associated with Ga_2O_3-based technology and the road ahead will be brainstormed.