Tunnel Junctions for New Architecture of Nitride Devices

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Recently, there has been increasing attention given to the interband tunnel junctions (TJs) for efficient carrier conversion between electrons and holes in nitride-based devices. Application of TJs creates more freedom in device design – e.g. eliminates the need for resistive p-type metal contact or enables vertical stacking of different devices. The main challenge in development of low resistance TJs in nitrides is related with growth process. For metal-organic vapor phase epitaxy (MOVPE) activation of the p-type conductivity in buried Mg doped InAlGaN layers is critical. Activation process requires physical hydrogen removal from Mg doped layers. Unfortunately, hydrogen cannot efficiently diffuse through n-type regions, making the MOVPE device design and processing (for lateral or vertical hydrogen removal) more complicated. One of the directions to overcome this issue is growth of III-N structures by plasma-assisted molecular beam epitaxy (PAMBE), since for PAMBE activation of Mg doped p-type layers is not necessary.

In this work we discuss development of PAMBE for nitride laser diodes (LDs) and light emitting diodes (LEDs) operating in spectral range from violet to green emission [1]. In particular, the recent progress in nitride devices with TJs grown by PAMBE is shown. We discuss the conditions for the growth of low resistance (In)GaN/InGaN/(In)GaN TJs with atomically flat morphology required for vertical integration of devices [2]. Incorporation of TJs to device structure enabled vertical integration of multicolor LDs and LEDs [3]. The TJs allows also to control the current path in distributed-feedback LDs and micro-LEDs [4]. It also opens the possibility to design new architecture of nitride devices which have inverted sequence of p and n type layers (similar to the structures on “hypothetical” p-type (0001) GaN substrate) [6]. Such device architecture allowed us to demonstrate LDs and LEDs operating at cryogenic temperatures, which is essential for future quantum computing and quantum cryptography applications [7]. Finally, we also discuss properties of bi-directional light emitting device, which is shining light from the same single quantum well for positive and negative voltage bias [8].

References

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