Wide bandgap technology: State-of-the-art and problems to solve

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Applications of wide bandgap (WBG) semiconductors, such as GaN, AlGaN, and InGaN, range from lighting and UV technology to high-power, radiation-hard, high-temperature, terahertz (THz) electronics and pyroelectronics. Wurtzite (hexagonal) symmetry makes these materials to be quite different from conventional cubic semiconductors. Spontaneous and piezoelectric polarization associated with the wurtzite crystal structure induces two-dimensional electron gases at AlGaN/GaN, AlInN/GaN, and AlGaN/InGaN interfaces with sheet concentrations 10–20 times higher than those in Si CMOS. A high current-carrying capability and a high breakdown field make these materials perfect for high power applications. Adjusting the energy gaps of $Al_xGa_{1-x}N$ and of $In_xGa_{1-x}N$ by varying the molar fraction changes the wavelength of light they emit or absorb and enables light emitters, solar cells, and photodetectors operating from THz and infrared to deep ultraviolet range. Blue, green, and white LEDs using InGaN revolutionized smart solid-state lighting. AlGaN UV LEDs are used for water purification, fighting antibiotic resistant bacteria and viruses, and dramatically increasing produce storage time. Indium nitride and boron nitride have potential to compete with the AlN/GaN family and diamond has reemerged not only as a substrate for a record heat removal but also as a viable THz detector material. The WBG technology has many difficult problems to solve. High dislocation density leads to a low efficiency of deep AlGaN UV LEDs and reliability problems in high-power devices. Nonuniformities of the electric field distribution cause premature breakdown. Using ultrathin WBG quantum well layers and nanowires and exploring radically new device designs might alleviate or even solve these problems.

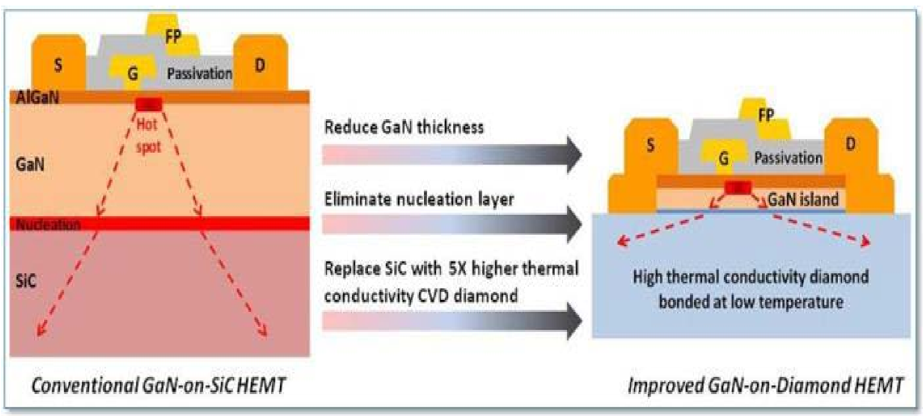

Fig. 1. Heat removal by diamond [P.-C. Chao *et al.*, *IEEE TED* **62**, 3658 (2015)].

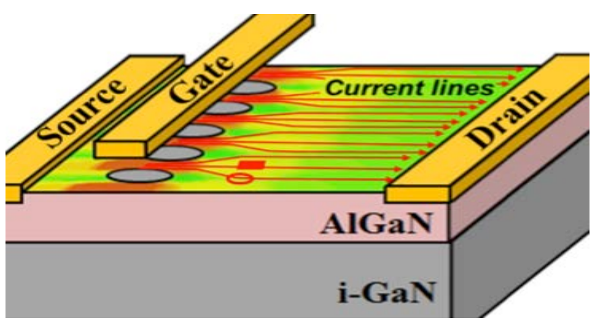

Fig. 2. Two-dimensional simulation of a perforated channel [G. S. Simin *et al., IEEE EDL* **35**, 449 (2014)].