semiconductors. An epitaxial growth technique using pulsed-gas feeding has been introduced, and a dramatic reduction in the threading-dislocation density (TDD) of AlN has been realized. Significant increases in internal quantum efficacy (IQE) have been achieved for AlGaN quantum-well (QW) DUV emissions by using low TDD AlN templates. The IQE of the DUV emission from AlGaN-QWs were enhanced by approximately two orders of magnitude by reducing TDD of AlN templates. We have observed quite high IQE value (>80%) by introducing In-segregation effects in AlGaN alloy. The electron injection efficiency (EIE) of the LEDs was also significantly increased by introducing a multi-quantum barrier (MQB) as an electron blocking layer (EBL). The maximum output power and external quantum efficiency (EQE) of the 280 nm DUV-LED were over 30 mW and 5 %, respectively. We have obtained the highest-record output powers and EQEs measured under room temperature (RT) continuous wave (cw) operations for LEDs with wavelength shorter than 260 nm, i. e., the output powers of 15 mW and 5 mW for the 247 and 237 nm DUV-LEDs, respectively. These achievements will contribute to accelerating the practical application of DUV-LEDs and to expanding them to a wide range of applications.

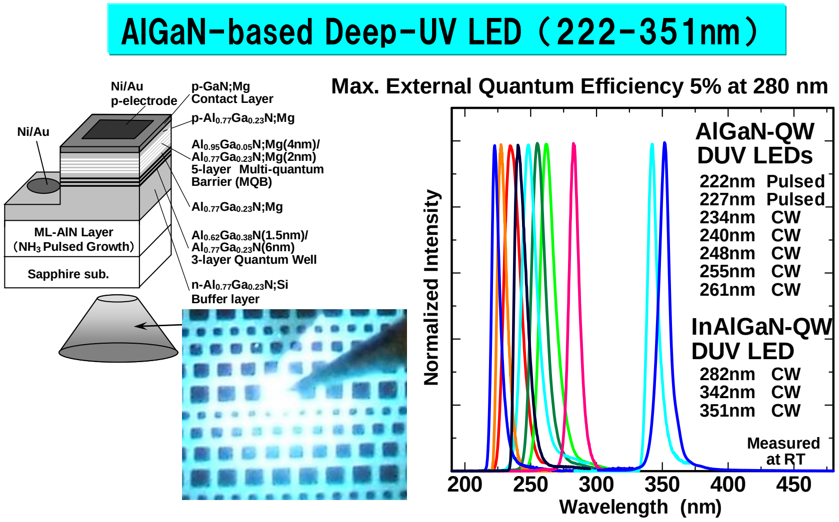

Fig. 3. Recent achievements of deep-UV LEDs using AlGaN-based semiconductors

2. Development of terahertz quantum-cascade lasers (THz-QCLs) (Hirayama, Terashima, Lin)

Terahertz quantum-cascade laser (THz-QCL) is promising as an advanced THz laser source, since THz-QCL has a lot of advantages, i.e., the size is quite small, continuous wave, high-power and high-efficiency operation is possible, the lasing line-width is quite sharp, and it is maintenance free (long-lifetime). However, there are still major problems preventing the THz-QCL from practical use, i.e., the lasing is obtained only at low temperature and the frequency range is limited. Therefore, our subjects for the THz-QCLs are to achieve room temperature (RT) lasing and to expand the lasing wavelength both to 5-12 THz and 0.5-1.2 THz-band. We have developed 3 THz-band QCLs with GaAs/AlGaAs semiconductor. We fabricated QCL superlattices (SLs) structures with one-atomic-layer accuracy flat hetero-interfaces by using a molecular beam epitaxy (MBE). We have introduced low-propagation-loss double-metal plasmon-waveguide (DMW) for THz-QCLs using silver (Ag) and cupper (Cu) metal. We obtained a high accuracy layer thickness control (within 1%) by measuring satellite peaks of X-ray diffraction rocking-curves. We then achieved 1.9 THz lasing of the GaAs-based THz-QCL. The maximum operating temperature was 160K. We also achieved the first observation of inter-subband emission from GaN-based QC structures by current injection.

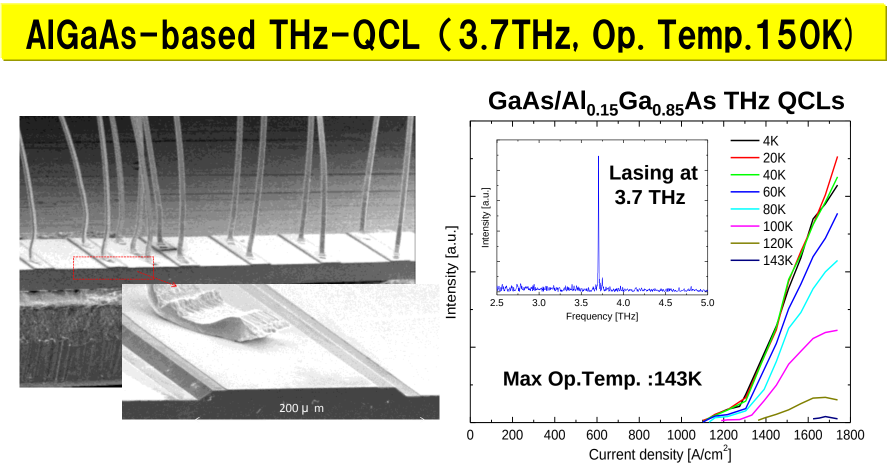

Fig. 4. Achievements of high-temperature operation of GaAs-based THz-QCLs

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