EECS 598-011 GaN-based Electronic Devices

Instructor: Elaheh Ahmadi

Lectures: TTh : 3-4:30 pm 1025 GGBL

Prerequisites: EECS 320 or equivalent, or permission of the instructor

Course Description:

GaN and its alloys with InN and AlN provide a wide range of direct bandgap (0.7 eV to 6.2 eV), which makes this material system suitable for optoelectronic applications such as laser diodes (LDs), light emitting diodes (LEDs), and solar cells. Besides, GaN has a large potential for high frequency and high-power electronics. Because of its high breakdown electric field in addition to high electron saturation velocity, GaN is a great candidate for high-power amplifiers and switches. In addition, GaN and its alloys with AlN and InN give the possibility of designing complicated heterostructures suitable for various lateral and vertical transistor structures such as high electron mobility transistors (HEMTs), hot electron transistors (HETs), current blocking vertical transistors (CAVETs), and trench MOSFETs.

In this class, we will review (Al, In, Ga)N material properties which make this material system so attractive for optoelectronics and electronics applications. We will then discuss two main epitaxial growth techniques, molecular beam epitaxy (MBE) and metal-organic CVD (MOCVD), utilized to grow (Al, In, Ga)N thin films. Ga-polar and N-polar HEMTs will be discussed in detail. Different designs of GaN-based vertical transistors for power applications will be covered.

Grading:

30 % Homework (2-3 sets of problems)

40% Presentation and report

30% Project (Sentaurus, BandEng)

Textbook:

Book chapters, review papers, and lecture notes will be posted online

Outline:

1. Overview of (Al,In,Ga)N crystal structure and material properties (3 lectures)
    - Spontaneous and piezoelectric polarization
    - Bandgap engineering
    - N-polar vs Ga-polar
2. Epitaxial growth (6 lectures)
    - GaN bulk substrates
    - Growth on foreign substrates (HVPE, MOCVD, MBE)
    - Thin film growth; N-polar vs Ga-polar
    - n-type and p-type doping
    - Polarization doping
3. GaN-based high electron mobility transistors (HEMTs) (8 lectures)
    - Ga-polar HEMTs
    - N-polar HEMTs
    - HEMTs for RF applications
    - HEMTs for power applications
4. Electron transport in HEMTs (5 lectures)
    - Different scattering mechanisms
    - Mobility vs charge density in Ga-polar vs N-polar HEMTs
5. GaN-based Vertical transistors (4 lectures)
    - Hot electron transistor for high frequency
    - CAVETs, trench MODFET, and Fin-FET for high power applications