EECS 598-004 GaN-based Electronic Devices

Instructor: Elaheh Ahmadi

Lectures: TTh : 3-4:30 pm Remote

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

Course Description:

Device performances are driven by new materials, scaling, and new device concepts such as bandstructure and polarization engineering. Semiconductor devices have mostly relied on Si but increasingly GaAs, InGaAs and heterostructures made from Si/SiGe, GaAs/AlGaAs etc have become important. Over the last few years one of the most exciting new entries has been the GaN based devices that provide new possibilities for lighting, displays and wireless communications. New physics based on polar charges and polar interfaces has become important as a result of the nitrides. For students to be able to participate in this and other exciting arena, a broad understanding of physics, materials properties and device concepts is required.
In this class, the methodology for deriving the high frequency properties of devices such as HBTs and FETs along with their equivalent circuits will be covered. High Electron Mobility Transistors will be then taught in detail. We will then discuss (Al,Ga,In)N material properties which make this material system so attractive for optoelectronics and electronics applications. Ga-polar and N-polar HEMTs will be discussed in detail. Different designs of GaN-based vertical transistors for high power and high frequency applications will be also covered.

Grading:

40 % Homework (4-5 sets of problems)

40% Presentation and report

20% Project (Sentaurus/Silvaco, BandEng, mobility modeling)

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