《Charge Transport Physics in Advanced Optoelectronic Materials》Syllabus

Course Number: NANA1904
Course Name: Charge Transport Physics in Advanced Optoelectronic Materials
Course Category: Elective course
Credits/Contact Hours: 2 credits/36 hours
Evaluation Method: In-class Presentation + Final Essay
Semester: 2019-2020 2nd semester
Prerequisites: NANA3012, NANA2041
Follow-Up: Graduation Project
Lecturer: Vincenzo PECUNIA
Syllabus Author: Vincenzo PECUNIA
Syllabus Reviewer: Qing Li
Text Book: Lecture Notes, Video Recording of Lectures, Research Journal Papers.

(1) Specific Goals for the Course

The primary goal of the course is for the students to acquire an understanding of the physics of charge transport in advanced optoelectronic materials. The students will acquire a mechanistic understanding of charge transport in relation to various degrees of homogeneity, order, and charge-lattice coupling. In addition to conventional charge transport theory, the students will learn about charge transport models specific to polycrystalline, amorphous, and molecular semiconductors—including grain boundary effects, the polaron model, localization, percolation, and hopping transport. Additionally, the course aims at providing the students with an understanding of how charge transport models are derived from experiment, especially in relation to emerging classes of optoelectronic materials (e.g., organic semiconductors, amorphous metal-oxide semiconductors, and metal-halide perovskites).
By the end of the course, students should be able to:
(i) Use knowledge in charge transport physics and emerging optoelectronic materials to analyze and quantify complex problems in the field of nanotechnology. (Support Graduation Requirements Indicator 1-2)
(ii) Conduct effective analysis and literature review to address complex problems related to charge transport physics in emerging optoelectronic materials. (Support Graduation Requirements Indicator 2-2)

(2) Topics for the Course

- Students can distinguish between different emerging optoelectronic materials; and can explain their technological applications and the role of charge transport in technological applications.
- Students are able to illustrate the main differences between conventional and emerging semiconductors (in terms of structural, compositional, and electronic aspects). Students can explain the different essential properties of emerging polycrystalline, amorphous, molecular

and polymeric semiconductors.

- Students can describe the nature of carriers in semiconductors, and can differentiate between quasi-free carriers and polarons. Students can explain the conduction process in semiconductors through the Drude-Sommerfeld approach.
- Students can describe charge transport in semiconductors via the Boltzmann equation. Students can explain the relaxation time approximation, and the effects of carrier scattering and energy relaxation.
- Students can describe the differences among various carrier scattering mechanisms (scattering with phonons; scattering at Coulomb potentials; scattering by neutral defects). Students can explain the effect of magnetic fields to carrier transport (Hall effect and magnetoresistance).
- Students can illustrate how resistivity and Hall effect are characterized experimentally.
- Students can explain how mobility is determined experimentally via space-charge-limited-current and time-of-flight characterization.
- Students can describe how mobility is determined experimentally via field-effect charge modulation. Students can illustrate the impact of defects on charge transport, and how defects can be characterized via deep-level transient spectroscopy.
- Students can explain the distinguishing features of charge transport in in polycrystalline semiconductors (role of grain boundaries; impact of doping; effective mobility; temperature dependence).
- Students can describe the basics of percolation theory and its general relevance to charge transport studies.
- Students can describe the impact of disorder on electronic states (disorder-induced localization and the Anderson transition).
- Students can illustrate the general models of charge transport in disordered materials, both via extended state, and via localized states (hopping charge transport).
- Students can relate the charge transport concepts they have learned up to this point by examining scientific papers on charge transport literature, and can present their understanding of the papers to the class.
- Students can relate the charge transport concepts they have learned up to this point by examining scientific papers on charge transport literature, and can present their understanding of the papers to the class.
- Students can describe charge transport models relevant to organic semiconductors.
- Students can illustrate charge transport models relevant to amorphous metal-oxide semiconductors.
- Students can independently explore an emerging topic in charge transport studies in the scientific literature, and can apply their knowledge developed throughout the course to prepare the final essay on this topic.

(3) Assessments for the Course

- **Course Score = Attendance (AT, 10%) + In-Class Presentation (PT, 30%) + Final Essay (FE, 60%)**

- **Achievement of Course Goal =(AT Mean Score*AT Weight*0.1 + PT Mean Score*PT Weight*0.3 + FE Mean Score*FE Weight*0.6) / (100*AT Weight*0.1 + 100*PT Weight*0.3 + 100*FE Weight*0.6)**

Course Goal	Attendance Weight	In-Class Presentation Weight	Final Essay Weight
(i) Use knowledge in charge transport physics and emerging optoelectronic materials to analyze and quantify complex problems in the field of nanotechnology. (Support Graduation Requirements Indicator 1-2)	1	0.5	0.5
(ii) Conduct effective analysis and literature review to address complex problems related to charge transport physics in emerging optoelectronic materials. (Support Graduation Requirements Indicator 2-2)	0	0.5	0.5

Rubrics for the Course:

Course Goal	90-100 (Excellent)	75-89 (Good)	60-74 (Pass)	0-59 (Fail)
(i) Use knowledge in charge transport physics of emerging optoelectronic materials to analyze and quantify complex problems in the field of nanotechnology. (Support Graduation Requirements Indicator 1-2)	Students possess comprehensive knowledge in charge transport physics of emerging optoelectronic materials, and are able to find innovative ways to analyze and calculate related complex problems.	Students possess wide knowledge in charge transport physics of emerging optoelectronic materials, and are able to use the knowledge to efficiently analyze and calculate related complex problems.	Students possess key knowledge in charge transport physics of emerging optoelectronic materials, and are able to use the knowledge to correctly analyze and calculate related complex problems.	Students lack key knowledge in charge transport physics of emerging optoelectronic materials, and/or are not able to use the knowledge to analyze and calculate related complex problems.
(ii) Conduct effective	Students are able to	Students are able	Students are able to	Students are

analysis and literature review to address complex problems related to charge transport physics in emerging optoelectronic materials. (Support Graduation Requirements Indicator 2-2)	conduct analysis in innovative ways and offer their viewpoints in literature review to address complex problems related to charge transport physics in emerging optoelectronic materials.	to conduct comprehensive analysis and thorough literature review to address complex problems related to charge transport physics in emerging optoelectronic materials.	conduct correct analysis and appropriate literature review to address complex problems related to charge transport physics in emerging optoelectronic materials.	unable to conduct analysis and literature review to address complex problems related to charge transport physics in emerging optoelectronic materials.