

## Micro/Nano Machined Metamaterials

EEL 4930 Section 0006

**Class Periods:** T, period 2-3 (8:30 – 10:25 am) and R, period 3 (9:35 – 10:25 am)

**Location:** 327 MAE-A

**Academic Term:** Spring 2023

### **Instructor:**

Name: Yong-Kyu “YK” Yoon

Email Address: [ykyoon@ece.ufl.edu](mailto:ykyoon@ece.ufl.edu)

Office Phone Number: (352) 392 - 5985

Office Hours: TW 1:00 – 1:50 pm or by appointment, Zoom: [ufl.zoom.us/j/3523925985](https://ufl.zoom.us/j/3523925985)

### **Teaching Assistant/Peer Mentor/Supervised Teaching Student:**

Please contact through the Canvas website

TBA

### **Course Description**

Course on the advanced micro-/nano machined metamaterials and their applications for radio frequency (RF)/microwave and optical devices such as waveguides, filters, antennas, optical lens, meta-optics, and analog computing (3 credit hours)

### **Course Pre-Requisites / Co-Requisites**

EEL 3472 Electromagnetic Fields and Applications, and EEL 3111C Circuits 1 , **Co-requisites:** None

### **Course Objectives**

To understand the metamaterial concept and the advanced microfabrication processes, and apply them for the design and implementation of compact and power efficient RF/microwave and optical devices.

### **Materials and Supply Fees**

N/A

### **Relation to Program Outcomes (ABET):**

The table below is an example. Please consult with your department’s ABET coordinator when filling this out.

| Outcome   | Coverage* |
|---|-----------|
| 1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics  | Medium    |
| 2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors                   | High      |
| 3. An ability to communicate effectively with a range of audiences  |           |
| 4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts | Medium    |
| 5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives   | Medium    |

|  |        |
|--|--------|
| 6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions |        |
| 7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies  | Medium |

\*Coverage is given as high, medium, or low. An empty box indicates that this outcome is not covered or assessed in the course.

### **Required Textbooks and Software**

Recommended book:

- Title: Metamaterials: Physics and Engineering Explorations
- Author: Nader Engheta and Richard W. Ziolkowski, Edited by
- Publication date and edition: 2006, IEEE Press and Wiley-Interscience
- ISBN number: 0471761028 9780471761020

Software:

High Frequency Structure Simulator (HFSS, ANSYS Inc.) and Manual  
COMSOL Multiphysics Simulation Tools (COMSOL, Inc.) and Manual

### **Recommended Materials**

Books:

David M. Pozar, Microwave Engineering, 3<sup>rd</sup> edition, Wiley, 2005  
Ricardo Marques, Ferran Martin, and Mario Sorolla, Metamaterials with Negative Parameters: Theory, Design and Microwave Applications, 2008, Wiley  
Christophe Caloz and Tatsuo Itoh, Electromagnetic Metamaterials, Wiley-Interscience, 2006

### **Course Schedule**

Introduction (w1)

Metamaterial definition and architectures (w2, 3)

- Basic RF concepts: Transmission line theory, Composite right/left handed (CRLH) transmission line approach
- Applications: Waveguide, Filter, Antenna etc.
- HFSS Tutorial

Resonant Metamaterials and Plasmonics (w4, 5)

- Resonant Metamaterials: Drude and Lorentzian model of metal, Artificial plasma freq., How to implement metamaterials  $n < 0$
- Plasma waves (Plasmons), Surface plasmon for dielectric-metal boundaries
- COMSOL Tutorial

Advanced Micro-/Nano Fabrication Processes (w6, 7)

- Bottom up processes: Self assembly, Carbon nanotube, Anodized aluminum oxide
- Top down processes: UV/X-ray/E-beam/Focused-ion-beam lithography, soft lithography, Scanning probe lithography, AFM lithography, Pattern transfer
- Additive processes: Electrodeposition, Atomic layer deposition, 3-D printing

Midterm Exam (Tentatively Mar. 1st, 2022)

Metaconductors (w9, 10)

- Negative magnetic permeability ( $\mu < 0$ ) in ferromagnetic materials
- Landau-Lifshitz-Gilbert Equation
- Low loss radio frequency conductors

Meta-optics (w11, 12, 13)

- Complementary split-ring-resonator (CSRR) loaded substrate integrated waveguide (SIW)
- Resonator/filter design

### ***Attendance Policy, Class Expectations, and Make-Up Policy***

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies. Click here to read the university attendance policies:

<https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/>

### ***Evaluation of Grades***

| <b>Assignment</b> | <b>Total Points</b> | <b>Percentage of Final Grade</b> |
|-------------------|---------------------|----------------------------------|
| Homework Sets (5) | 100 each            | 10%                              |
| Midterm Exam      | 100                 | 30%                              |
| Final Exam        | 100                 | 30%                              |
| Term Project      | 100                 | 30%                              |
|                   |                     | 100%                             |

EEL 4930 has computer software based simulation and design homework and a term project. Term project reports are required.

This course is co-listed with the graduate class. The homework portion of the graduate section may involve additional work and more advanced concepts with respect to the undergraduate section. The exams would involve additional questions for the graduate section with respect to the undergraduate section. Grading for the homework and projects are different from the undergraduate course. The graduate and undergraduate sections will be graded separately, for which the graduate section could additional problems and different weights for all problems. The final project shall be on the topics of metamaterials and their applications learned throughout the course, and consist of the following parts: (i) Motivation / Background, (ii) Technical Approach (iii) Results, (iv) Discussions, and (v) Conclusions. It will be graded according to the following percentages: 30% for parts (i), 45% for parts (ii) and (iii), 25% for parts (iv) and (v). Parts (i) and (iv) shall include discussions on relations and comparisons between metamaterial and other approaches, which need to be comprehensive.

### ***Grading Policy***

| <b>Percent</b> | <b>Grade</b> | <b>Grade Points</b> |
|----------------|--------------|---------------------|
| 90.0 - 100.0   | A            | 4.00                |
| 87.0 - 89.9    | A-           | 3.67                |
| 83.0 - 86.9    | B+           | 3.33                |
| 80.0 - 82.9    | B            | 3.00                |
| 77.0 - 79.9    | B-           | 2.67                |
| 73.0 - 76.9    | C+           | 2.33                |
| 70.0 - 72.9    | C            | 2.00                |
| 67.0 - 69.9    | C-           | 1.67                |
| 63.0 - 66.9    | D+           | 1.33                |
| 60.0 - 62.9    | D            | 1.00                |
| 57.0 - 56.9    | D-           | 0.67                |
| 0 - 56.9       | E            | 0.00                |

More information on UF grading policy may be found at:

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

### ***Students Requiring Accommodations***

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is

important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

### ***Course Evaluation***

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

### ***In-Class Recording***

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

### ***University Honesty Policy***

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### ***Commitment to a Safe and Inclusive Learning Environment***

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, [jpennacc@ufl.edu](mailto:jpennacc@ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

### **Software Use**

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### **Student Privacy**

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

### **Campus Resources:**

#### Health and Wellness

##### **U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**Counseling and Wellness Center:** <https://counseling.ufl.edu>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

##### **Sexual Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

##### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

#### Academic Resources

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu).  
<https://lss.at.ufl.edu/help.shtml>.

**Career Connections Center**, Reitz Union, 392-1601. Career assistance and counseling; <https://career.ufl.edu>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.

<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.

<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus:** <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>;<https://care.dso.ufl.edu>.

**On-Line Students Complaints:** <https://distance.ufl.edu/state-authorization-status/#student-complaint>.