UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Nanomaterial-Driven Wearable Antennas, Circuits, and Wireless Smart Skins"

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Short Abstract:

Nanomaterial and micromachining-enabled soft and wearable electronics hold great promise in enabling telehealth and telemedicine. Wearable electronic devices transducing physical, chemical, and/or physiological responses to electrical signals, have been used in health monitoring, such as real-time detection of blood pressure, respiration rates, body temperature, and human motion. Combined with the ever-improving wireless and radio-frequency (RF) technologies, wearable electronic devices can transmit information in real time and be powered wirelessly in a passive and energy-saving manner. This short course will review the recent progress of nanomaterials and microsystems, as well as their unique electrical, (bio-)chemical, thermal, and mechanical properties that make them suitable for wearable antenna and circuit applications. This short course will also discuss challenges and breakthroughs in wireless sensing and interrogation technologies for wearable IoT devices.

Objectives

- To provide broad context and conceptual insights into wearable electronics for intelligent healthcare monitoring and diagnosis
- To review emerging nanomaterials and microstructures for various types of flexible, stretchable and biocompatible wearable sensors
- To provide an overview of wireless communication protocols (RFID, NFC, BLE etc.) and body-area networks for wearables
- To learn the antenna and circuit designs and electromagnetic considerations for wearable technologies
- To study wireless power transfer for wearable and implantable devices, and to apply energy harvesting modulus to covert ambient radiation or biomechanical energy into electricity

Keywords:

Electromagnetics, Sensors, Materials/Designs/Implementations of Wearable Antennas and Circuits, Telemedicine, IoTs

Course Contents in brief:

(1) Introduction to wireless health, telemedicine, and telediagnosis (2 hours)

(2) Introduction to smart skins and wearable technologies (2 hours)

(3) Micro/nano-driven wearable antennas and circuits: material selection, design and fabrication (10 hours)

(4) Wireless sensing, communication and energy harvesting for IoT sensors (4 hours)

(5) Signal processing and multisensor fusion (2 hours)

Total # of hours of lecture:

20 hours

References:

(1) Rogers, John A., Roozbeh Ghaffari, and Dae-Hyeong Kim, eds. Stretchable bioelectronics for medical devices and systems. Switzerland: Springer, 2016.
(2) Sazonov, Edward, ed. Wearable Sensors: Fundamentals, implementation and applications. Academic Press, 2020.
(3) Someya, Takao, and Masayuki Amagai. "Toward a new generation of smart skins." Nature biotechnology 37.4 (2019): 382-388.
(4) Pozar, David M. Microwave engineering: theory and techniques. John Wiley & Sons, 2021.
(5) Balanis, Constantine A. Antenna theory: analysis and design. John Wiley & Sons, 2015.
(6) Tian, Xi, et al. "Wireless body sensor networks based on metamaterial textiles." Nature Electronics 2.6 (2019): 243-251.
(7) P. Y. Chen et al., “Generalized Parity-Time Symmetry Condition for Enhanced Sensor Telemetry,” Nature Electronics, Vol. 1, 297–304 (2018).
(8) Y. Xu et al. “Porous Silver Nanowire Composites with Strain-Insensitive Conductance and Ultralow Percolation Thresholds for Wireless Stretchable Bioelectronics Phase-Separated Porous Nanocomposites for Wireless Stretchable Bioelectronics,” Nature Nanotechnology, Vol. 19, 1158–1167 (2024).
(9) Z. Ye et al., “A Breathable, Reusable and Zero-Power Smart Face Mask for Wireless Cough and Mask-Wearing Monitoring,” ACS Nano, Vol. 16, 5874-5884 (2022).

Requirements:

Students should be familiar with (1) basic electrical circuits, (2) electromagnetics, and (3) basic understanding of nanomaterials, nanofabrication and micromachining. Open only to students enrolled in professional science and engineering programs.

CV of the Teacher

Biography: Prof. Pai-Yen Chen (Fellow IEEE) is a Professor in the Department of Electrical and Computer Engineering at the University of Illinois Chicago (UIC). He received the Ph.D. degree from the University of Texas at Austin in 2013, and M.S. and B.S. degrees from National Chiao Tung University in Taiwan in 2006 and 2004, respectively. He was a Research Scientist at Intellectual Ventures Laboratory (2013-2014) and a Research Staff in the Taiwan Semiconductor Research Institute (2006-2009). He has been involved in multidisciplinary research on applied electromagnetics, RF/microwave antennas and circuits, wireless sensors and systems, smart skins, bioelectromagnetic, nanophotonics, and nanoelectronics. He has published numerous papers in high-ranked journals including Nature, Nature Electronics, Nature Nanotechnology, Nature Communications, Science Advances, and various IEEE transactions. He co-authored a book entitled Transformation Wave Physics and 10 US patents. He has received several prestigious awards, including NSF CAREER Award, IEEE Sensors Council Technical Achievement Award (advanced career), IEEE Sensors Council Distinguished Lecturer, IEEE Sensors Council Young Professional Award, IEEE AP-S Raj Mittra Travel Grant (RMTG) Award, IEEE Chicago Distinguished R&D Award, SPIE Rising Researcher Award, ACES Early Career Award, PIERS Young Scientist Award, URSI Young Scientist Award, IOP Emerging Leader in Measurement Science and Technology, AFRL Faculty Fellowship, University of Illinois Scholar, UIC Researcher of the Year, UIC College of Engineering Faculty Research Award, Donald Harrington Fellowship, United Microelectronics Corporation Scholarship, and quite a few best paper and design awards from IEEE flagship conferences. He currently serves as Senior Editor of IEEE Journal of Selected Areas in Sensors and Associate Editor of IEEE Transactions on Antennas and Propagation, IEEE Antennas and Wireless Propagation Letters, and IEEE Sensors Journal. He was a former Associate Editor of Advanced Electromagnetics, IEEE Journal of Radio Frequency Identification, and IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology, and former Guest Editor of several international journals. He currently serves as the chair of IEEE Chicago AP-S/MTT-S Joint Chapter. He was the chair and founder of the IEEE Chicago Sensors Chapter and the ACES Board of Directors.

Final Exam: The final exam will be based on presentations. The student should conduct literature survey for the state-of-the-art wearable devices and future applications.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

Day1 – April 8, 2025: 13:30-17:30 Introduction to wireless health, telemedicine, and telediagnosis (2 hours); Introduction to smart skins and wearable technologies (2 hours)

Day2– April 9, 2025: 13:30-17:30 Micro/nano-driven wearable antennas and circuits: material selection, design and fabrication (4 hours)

Day3 – April 10, 2025: 13:30-17:30 Micro/nano-driven wearable antennas and circuits: material selection, design and fabrication (4 hours)

Day4 – April 11, 2025: 9:00-13:00 Micro/nano-driven wearable antennas and circuits: material selection, design and fabrication (2 hours); Wireless sensing, communication and energy harvesting for IoT sensors (2 hours)

Day5 – April 11, 2025: 14:00-18:00 Wireless sensing, communication and energy harvesting for IoT sensors (2 hours); Signal processing and multisensor fusion (2 hours)