Biomedical Ultrasound, Fundamentals of Imaging, and Micro Machine Transducers

Course Instructor: Dr. Hardik J. Pandya

Department of Electronic Systems Engineering

Indian Institute of Science, Bangalore

Lecture - 12

Welcome to the course on Biomedical Ultrasound, Fundamentals of Imaging, and Micro Machine Transducers. This course will be conducted by three instructors: Professor Himanshu Shekhar and Professor Karla Mercado Shekhar from IIT Gandhinagar, and Professor Hardik Jeetendra Pandya from IISc Bangalore. The course aims to teach students an essential area of research, enhancing their understanding of image processing, signal processing, fabrication techniques, wave propagation, acoustic impedance, and different kinds of attenuation and reflection intensities. The course will also cover scattering, refraction, focusing, speckle activities, and the concept of piezoelectricity, along with the electrical and mathematical modeling used in this field.

We will explore the structure and function of ultrasound transducers, including matching and backing layers and impedance effects. Typically, ultrasound transducers are known for fetal monitoring, but this course will delve into their internal workings, including the composition of ultrasound transducers, imaging tools, matching layers, backing layers, and impedance values. It will also cover data processing, noise reduction, image modes, and image reconstruction.

An interesting question posed is whether an array of transducers can be used as both a transmitter and receiver. For example, how can an array of 8 by 1 or 1 by 8 transducers be used effectively? We know that ultrasound transducer works on piezoelectricity, that means if you apply a voltage there will be change in pressure apply a pressure change in voltage but how does it come into realization. We will discuss the fabrication of ultrasound transducer arrays, including piezoelectric micromachined ultrasound transducers (PMUTs). The course will explain the process from sand to silicon, including CZ and FZ techniques.

We will also cover thermal oxidation in MOSFETs, which involves growing field oxides and masking oxides on silicon wafers. For piezoelectric transducers, there is a bottom electrode, a top electrode, and a piezoelectric material sandwiched between them. The techniques for depositing these layers, such as Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD), will be discussed. The micro-machining process, including bulk and surface micro-machining, and different etching techniques, such as wet and dry etching, will also be covered.

Photolithography, specifically UV photolithography, will be explored as a method to pattern materials for specific applications like elastography. We will discuss ultrasound safety, bio-effects,

imaging artifacts, and image regeneration using ultrasonic transducers. So all things in a nutshell we are not only going to learn about fabrication, we are not only going to learn theory about fabrication or process flow, we are also looking at the videos, we have a lab videos for you which are recorded right from thermal evaporation, E-beam evaporation, sputtering, we have lithography demonstration for you so that you can get a better hold of what you are learning.

The course will start with the basics of ultrasound, covering wave propagation and acoustic impedance, and then move to imaging modalities, imaging reconstruction and high-end applications in elastography. The intention is to provide a comprehensive understanding of these topics within a 30-hour timeframe, enabling students to apply this knowledge in research or other fields, not limited to healthcare.

Ultrasound has diverse applications beyond healthcare, and this course aims to broaden the understanding of these applications. Using the NPTEL platform, students can ask questions through the forum, and the instructors will be available to respond. The course is beneficial for undergraduate and postgraduate students in engineering disciplines such as mechanical, electronics, electrical, and physics, as well as anyone interested in understanding how ultrasound works and how it can be fabricated.