Approval: 8th Senate Meeting

Course Name: Nanomanufacturing

Course Number: ME509

Credits: 3-0-0-0

Prerequisites: None

Elective or Core: Elective

Intended for: UG (3rd year onwards-all branches)/ PG

Course Preamble: The research on nanotechnology is taking a rapid path towards nonmanufacturing to make the breakthroughs of nanoscience/technology in to practical reality. The economic and scientific promise of nanotechnology will not be realized, if wefail to move forward and show commercial viability. The main objective of the courser is to prepare the students to latest advances in both "top down" and "bottom up" approaches and to address the fundamental challenges in nonmanufacturing. Also the course will be motivated to understand the size reduction in the electronic, memory and energy devices and related progress in industry. This new elective course on nanomanufacturing will be complementary to the existing conventional courses in nanoscience and nanotechnology that focuses on underlying science. The designed course will also bridge the gap between the engineering (mechanical and electrical), industrial developments and underlying basic science research.

Course Outline*:* Nanomanufacturing involves large scale, reliable, economic and controlled production of nano scale materials, structures, devices and products. This course will cover various aspects of nanomanufacturing with major emphasis on the growth of 1D (CNT, Si nanowire) and 2D nanostructures (Graphene and other 2D materials) from chemical vapor deposition, thin film deposition techniques, self-assembly, nanopatterning along with several lithography and microfabrication techniques. This course also will include techniques involved in nanoscale characterization and fabrication.

Module-1: Introduction to Nanosceience and Nanotechnology [6 Lectures]

Historical developments in size reduction, fundamentals of nanoscale materials and their interactions, properties of nanocrystalline materials, size effects and quantum confinement in semiconductors, different types of nanostructures (zero, one and two dimensional) with specific examples, nanoscience in electronics, mechanics, photonics, biomedical and energy, nanomanufacturing objectives and opportunities, nanomanufacturing challenges.

Module-2: Characterizations/fabrication techniques for nanostructures [4 Lectures]

Basic concepts in microscopy, evolution of microscopes, electron microscopy and scanning probe microscopy for structural, microstructural, topological analysis, atomic order and compositional analysis. Application of microscopes in nanoscale characterizations. In- situ

microscopy for the growth and fabrications of various nanostructures. Interface of microscopy with nanofabrication techniques.

Module-3: Top down approaches for nanomanufacturing (subtractive) [6 Lectures]

Concepts in top down nanomanufacturing, Mechanosynthesis-ball milling, Focused ion beam milling, thin film fabrication, thermal evaporation, E beam evaporation, Sputtering (DC, RF, reactive), thin film growth mechanism and stress evolution, Essentials of photolithography, Ebeam lithography, nanoimprint lithography, Etching methods for fabrication, dry etching and wet etching.

Module-4:Bottom up approaches for nanomanufacturing (additive) [8 Lectures]

Solution synthesis of nanostructures, basics of size and shape control, growth by aggregation and oriented attachment, growth from vapor phase, Atomic layer deposition, Chemical vapor deposition, Growth of carbon nanotubes, graphene and 2D materials, Vapor-liquid-solid method, Vapor phase epitaxy, Molecular beam epitaxy, Growth of important semiconductor materials; Si, GaN nanowires.

Module-5: Advanced nanomanufacturing techniques and assembly [4 Lectures])

Non lithographic techniques for nanomanufacturing, Template assisted methods, Template less nanopatterning, self-assembly, electric field assisted assembly.

Module-6: Selected Topics in Nanomanufacturing and Microfabrication [7 Lectures]

Introduction to VLSI technology, Electrochemical Processing and MEMS/NEMS technology, Challenges and Applications of nanomanufacturing in electronics, display, nanomedicine, green energy building and smart surfaces. Issues of yield and rate of production. High rate and scalable nanomanufacturing; roll to roll manufacturing for nanomaterials. Industrial R& D activities, economics and environmental concerns.

Text Books:

1. Nanomanufacturing Handbook,Ahemed Busnaina, CRC press, 2006
2. Fundamentals of Microfabrication and Nanotechnology, Marc J.Madou, CRC Press, 2011
3. Emerging nanotechnologies for manufacturing by Waqar Ahmed& M.J Jackson William Andrew Publishing, 2009
4. Open course materials (MIT& University of Michigan) and Journal articles