Course Number : ME 515
Course Name : **Carbon Materials and Technology**
Credits : 3-0-0-3
Prerequisites : **None (basic knowledge of material science expected)**

Intended for : M.Tech. / M.S./ Ph.D./ B.Tech. (4th year)/ M.Sc.

Distribution : Free Elective

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1. Preamble:

This course will introduce the students to the preparation and structure-property relationship of various carbon materials for the purpose of device manufacturing. Carbon is one of the most important technological materials in modern-day industries. Consequently, a lot of cutting-edge research is also focused on carbon materials and technology, both in India and internationally. Applications of carbon range from micro/ nano biomedical devices to automobile and aerospace industry, smart textiles, water and environmental pollution controllers and energy storage devices. At present there is no comprehensive course being offered at IIT Mandi that is specific to carbon, and/or is focused on explaining the properties of different carbon materials based on their underlying microstructure. Proposed course not only covers carbon as a material but also includes basic manufacturing techniques and real-life device examples. Notably, carbon is a hard and brittle material that is extremely difficult to machine. It is therefore not compatible with the traditional manufacturing techniques. Moreover, often each carbon material can only be manufactured using a certain technique, which means that carbon technology must always be taught in a "material-manufacturing pair". All of these factors have been considered in the proposed course modules that will make this course unique and useful to all students, whether they pursue higher studies or wish to join an industry.

2. Course Modules:

Module 1: Introduction to carbon (6 hours)

- Why should one study carbon materials and manufacturing?
- Carbon economy
- Atomic structure and hybridization
- Carbon allotropes
- Nomenclature and terminology

Module 2: Microstructure of carbon materials (15 hours)

(a) Bulk industrial carbon
- Graphite: natural and pyrolytic
- Activated carbon
- Glass-like carbon
- Granular amorphous carbon

(b) Carbon fibers and composites
- Activated carbon fiber
- Carbon fiber reinforced plastics

(c) Carbon nanomaterials
- Graphene
- Carbon Nanotube
- Fullerene
- Graphite whiskers

- Diamond-like carbon

(d) Characterization of carbon materials (discussed in a-c) by X-Ray Diffraction, Raman spectroscopy and electron microscopy

Module 3: Raw materials (4 hours)

- Polymer precursors (Polyacrylonitrile, cellulose, resins, PVC etc.)
- Needle coke (petroleum and pitch based)
- Coal and its distillation
- Gaseous hydrocarbons (for CVD)
- Carbon yield and mechanism of carbonization (thermodynamic and kinetic aspects)

Module 4: Properties of carbon materials (4 hours)

- Crystallinity and electrical conductivity
- Electrochemistry and surface chemistry
- Mechanical and thermal properties

Module 5: Manufacturing techniques for carbon materials (4 hours)

- Pyrolysis (activated carbon, glassy carbon, pyrolytic graphite)
- Electrospinning (carbon fibers)
- Chemical vapor deposition (graphene and CNT)
- Composite preparation (material/ binder interface)
- Mechanical property testing methods

Module 6: Applications (6 hours)

- Graphite electrodes
- Carbon-fiber composites in automobile industry
- Carbon-based micro and nano devices (sensors, microelectrodes etc.)
- Filters and adsorbers

Module 7: Special topics (3 hours)

- Health and environmental safety of carbon nanomaterials
- Carbon-based flexible electronics
- Future of carbon technology

3. **Textbook:** Timothy D. Burchell, *Carbon Materials for Advanced Technologies.* (Elsevier,1999), (ISBN: 978-0-08-042683-9)

4. **Reference books:**

1. Jenkins, G. M. & Kawamura, K. *Polymeric carbons--carbon fibre, glass and char*. (Cambridge University Press, 1976).
2. Marsh, H. & Rodríguez-Reinoso, F. *Activated carbon*. (Elsevier, 2006).
3. Kong, L. B., *Carbon nanomaterials based on graphene nanosheets*. (CRC Press, Taylor & Francis Group, 2017).
4. Chung, D.D.L. *Carbon fiber composites*. (Butterworth-Heinemann, 1994).