



**Approved in 44<sup>th</sup> BoA Meeting (24-11-2021)**

**Course number** : EN 509  
**Course Name** : Functional Materials for Energy Engineering  
**Credit Distribution** : 3-0-0-3  
**Intended for** : UG/PG (Compulsory for MTech. in Materials and Energy Engineering, and Elective for others)  
**Prerequisite** : None  
**Mutual Exclusion** : ME 609

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### **1. Preamble:**

This course is designed keeping the students coming from diverse fields in mind. It will provide a sound conceptual background in solid state physics necessary for understanding the functionality displayed by various materials especially for energy applications. Finally, to show the utility of the concepts learned in the course, some examples of functionality driven energy devices will also be discussed

### **2. Course Modules with quantitative lecture hours:**

- **Module 1:** Introduction: Definition of functional materials, Different kind of functional materials; Inorganic and organic functional materials, Metal organic framework based materials, Hybrid organic-inorganic Perovskites, Use of functionalities of materials in fabricating devices, Causes for observed functionality in a material; Functionality arising due to (i) electronic, (ii) spin, and (iii) ionic degrees of freedom; Exploitation of combined effects in designing new functional materials. [4 Hours]
- **Module 2:** Functionality driven by electronic degrees of freedom: Atoms and crystalline solids; electronic states of atoms and crystalline solids; Formation of bands in crystalline solids; Band dispersions; Density of states; Metals, semiconductors and insulators; Direct and indirect band gap semiconductors; Formation of impurity bands in the p-type and n-type semiconductors; Electrons effective mass in a semiconductor; Transport and optical properties of a semiconductor; Opto-electronic materials. [12 Hours]
- **Module 3:** Functionality driven by spin degrees of freedom: Formation of magnetic moment in an atom; Spin and orbital part of magnetic moment in a solid; Magnetization of a solid; Diamagnetic, paramagnetic, ferromagnetic, and antiferromagnetic materials; Different kind of antiferromagnetic structures; Exchange interaction; Determination of magnetic transition temperature using mean-field theory; Formation of domain wall in ferromagnetic material; Soft and hard ferromagnets; CMR/GMR materials. [10 Hours]
- **Module 4:** Functionality driven by ionic degrees of freedom: Covalent, ionic and metallic solids; Formation of dipole moment; Polarization of a material; Paraelectric, ferroelectric, antiferroelectric, piezoelectric, and pyroelectric materials; formation of domain wall in ferroelectric material; Multiferroic materials. [6 Hours]
- **Module 5:** Functionality driven Energy Devices: Energy efficient devices, Light emitting diodes, Power Electronic Devices, Quantum computers and devices, Opto-electronic devices, Thermoelectric Devices, Electro caloric and Magneto caloric devices,

**3. Text books:**

- Solid State Physics by N.W.Ashcroft and N.D. Mermin, 1976, Harcourt College Publishers
- The Physics of Semiconductors: An Introduction Including Devices and Nanophysics by Marius Grundmann, 2010, Springer Berlin Heidelberg New York

**4. References:**

- Electronic Structure: Basic Theory and Practical Methods by R.M.Martin, 2004, Cambridge University Press
- Multiferroicity: the coupling between magnetic and polarization orders by K.F. Wang, J. – M. Liu, and Z.F.Ren, Advances in Physics 58, 321 (2009)

**5. Similarity with the existing courses:**

**(Similarity content is declared as per the number of lecture hours on similar topics)**

S. No.		Course Code	Similarity Content	Approx. % of Content
1.	Functional Materials	ME609	Module 1-4	75%

**6. Justification of new course proposal if cumulative similarity content is >30%:**

The course ME609 is modified into EN 6XX to cater the basics of the Materials and Energy Engineering program. The modifications are brought in two areas-

1. The name is changed from Functional Materials to Functional Materials for Energy Engineering
2. The last module is changed from earlier ME 609 to provide a broader outlook of energy engineering devices and their material dependence. This course will act as the core course for M Tech MEE students and hence this modification was mandatory, especially to look after the students from varying backgrounds.