

# MNE8102: KINETICS IN NANOSCALE MATERIALS

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## Effective Term

Semester A 2025/26

## Part I Course Overview

### Course Title

Kinetics in Nanoscale Materials

### Subject Code

MNE - Mechanical Engineering

### Course Number

8102

### Academic Unit

Mechanical Engineering (MNE)

### College/School

College of Engineering (EG)

### Course Duration

One Semester

### Credit Units

3

### Level

R8 - Research Degree

### Medium of Instruction

English

### Medium of Assessment

English

### Prerequisites

Background knowledge in related disciplines is required and course registration will be subject to the approval of the Course Examiner

### Precursors

Nil

### Equivalent Courses

Nil

### Exclusive Courses

Nil

## Part II Course Details

### Abstract

The aim of this course is to explain why the subject of kinetics in nanoscale materials is of wide interest today; because of its link to nanotechnology. In recent years, a major development in science and engineering is nanoscience and nanotechnology. At the moment, the research and development on nanoscale materials science for nanotechnology is ubiquitous for example, the study of silicon, metal, and oxide nanowires. To build the nanowire device hetero-structure of silicide/Si/silicide requires the study of line contact reaction between Si and metal nanowires to form the silicide electrodes. To use Ag nanowire mesh as the transparent conducting electrodes on flexible solar cells requires the study of point contact reaction between two Ag nanowires. What is unique in kinetics in nanoscale materials is the dominant effect of Gibbs-Thomson potential energy, high concentration gradient, large quantity of non-equilibrium vacancies, very few dislocations, yet very high density of nanotwins and grain boundaries.

### Course Intended Learning Outcomes (CILOs)

CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1 Learn the unique microstructure and kinetic behaviors of nanoscale materials such as nanospheres, nanowires, nanothickness thin films, and nanostructure in bulk-type materials.		x	x	
2 Understand linear and non-linear diffusion equations and solutions for nano materials.			x	
3 Analyse Kirkendal effect and inverse Kirkendall effect and their interaction in core-shell nanoscale materials.			x	
4 Learn spinodal decomposition and chemical potential in inhomogenous solid solution and interdiffusion in man-made superlattices.			x	
5 Identify and apply ripening kinetics among nano-precipitate and the mean-field assumption in LSW theory of ripening			x	
6 Analyse and design thermodynamics and kinetics of homogeneous nucleation. Homogenous nucleation is rare in bulk materials and that is why F. C. Frank' s model of spiral growth around a screw dislocation was invented to overcome homogeneous nucleation. The link between Zeldowitch' s steady state nucleation theory and experimental study of repeating homogeneous nucleation of epitaxial silicide in Si nanowires will be derived and applied to both functional materials.			x	

#### A1: Attitude

Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

#### A2: Ability

Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

#### A3: Accomplishments

Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

### Learning and Teaching Activities (LTAs)

LTAs		Brief Description	CILO No.	Hours/week (if applicable)
1	Lecture	The emphasis will be on learning the decomposition, growth, thermodynamics, microstructure and diffusion kinetics associated with the synthesis of nanostructured materials in different geometrical forms.	1, 2, 3, 4, 5, 6	39 hours

### Assessment Tasks / Activities (ATs)

ATs		CILO No.	Weighting (%)	Remarks ("- " for nil entry)	Allow Use of GenAI?
1	Quiz	1, 2, 3, 4, 5, 6	80	-	No
2	Assessment of Term Report	6	20	-	Yes

### Continuous Assessment (%)

100

### Examination (%)

0

### Assessment Rubrics (AR)

#### Assessment Task

Quiz (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

#### Criterion

Ability to describe the types of nanomaterials and their microstructural evolution, perform thermodynamic and kinetic calculations associated with their synthesis (dissociation or growth) towards developing them in various geometrical forms.

#### Excellent

(A+, A, A-) High

#### Good

(B+, B, B-) Significant

#### Fair

(C+, C, C-) Moderate

#### Marginal

(D) Basic

#### Failure

(F) Not even reaching marginal levels

**Assessment Task**

Assessment of Term Report (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

**Criterion**

Ability to systematically design a scheme to synthesise a typical nanomaterial and perform associated analysis with one or two more students as a small group. In addition, the methodologies adopted and the results obtained should be documented in the form of a scientific report.

**Excellent**

(A+, A, A-) High

**Good**

(B+, B, B-) Significant

**Fair**

(C+, C, C-) Moderate

**Marginal**

(D) Basic

**Failure**

(F) Not even reaching marginal levels

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**Assessment Task**

Quiz (for students admitted from Semester A 2022/23 to Summer Term 2024)

**Criterion**

Ability to describe the types of nanomaterials and their microstructural evolution, perform thermodynamic and kinetic calculations associated with their synthesis (dissociation or growth) towards developing them in various geometrical forms.

**Excellent**

(A+, A, A-) High

**Good**

(B+, B) Significant

**Marginal**

(B-, C+, C) Moderate

**Failure**

(F) Not even reaching marginal levels

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**Assessment Task**

Assessment of Term Report (for students admitted from Semester A 2022/23 to Summer Term 2024)

**Criterion**

Ability to systematically design a scheme to synthesise a typical nanomaterial and perform associated analysis with one or two more students as a small group. In addition, the methodologies adopted and the results obtained should be documented in the form of a scientific report.

**Excellent**

(A+, A, A-) High

**Good**

(B+, B) Significant

**Marginal**

(B-, C+, C) Moderate

**Failure**

(F) Not even reaching marginal levels

## Part III Other Information

**Keyword Syllabus**

Past, present, and future microelectronic technology, Overview of kinetic processes in nanoscale materials, Linear and non-linear diffusion, Kirkendall effect and inverse Kirkendall effect, Ripening, Spinodal decomposition, Nucleation events in bulk, thin film, and nanoscale materials, and Growth events in contact reactions on Si; plane, line, and point contacts.

**Reading List****Compulsory Readings**

Title	
1	There is no textbook on this subject, but lecture notes of all the lectures are available and will be distributed to all the students in the class. The following books on kinetics in phase transformations are helpful.

**Additional Readings**

Title	
1	D. A. Porter and K. E. Easterling "Phase transformation in metals and alloys," Chapman & Hall, London (1992).
2	Paul Shewmon, 2nd edition on "Diffusion in solids," TMS, Warrendale, Pa. (1989).
3	King-Ning Tu and Audriy M. Gusak, "Kinetics in Nanoscale Materials," John Wiley and Sons, (2014).