上海交通大学研究生课程开设申请表

New Graduate Course Application Form, SJTU

<table>
<tr><th colspan="5">课程基本信息 Basic Information</th></tr>
<tr><td rowspan="2">*课程名称
Course Name</td><td colspan="4">（中文 Chinese）固态相变原理</td></tr>
<tr><td colspan="4">（英文 English）Principles of Solid State Transformations</td></tr>
<tr><td>*学分
Credits</td><td>3</td><td>*学时
Teaching Hours</td><td colspan="2">48（1 学分≥16 课时）</td></tr>
<tr><td>*开课学期
Semester</td><td>春季学期 Spring</td><td>*是否跨学期
Cross-semester?</td><td>否 No</td><td>跨 Spanning over 个学期 Semesters（含夏季学期）。</td></tr>
<tr><td>*课程性质
Course Category</td><td>专业课 Specialized Course</td><td>*课程分类
Course Type</td><td colspan="2">全日制课程 For full-time students</td></tr>
<tr><td>*授课语言
Instruction Language</td><td>中文 Chinese</td><td>主要授课方式
Teaching Method</td><td colspan="2">课堂教学 In class teaching</td></tr>
<tr><td>*成绩类型
Grade</td><td>等第制 Letter grading</td><td>主要考核方式
Exam Method</td><td colspan="2">笔试 Written Exam</td></tr>
<tr><td>*开课院系
School</td><td colspan="4">材料科学与工程学院</td></tr>
<tr><td>所属学科
Subject</td><td colspan="4">材料科学与工程</td></tr>
<tr><td rowspan="2">负责教师
Person in charge</td><td>姓名 Name</td><td>工号 ID</td><td>单位 School</td><td>联系方式 E-mail</td></tr>
<tr><td>郭正洪</td><td></td><td>材料科学与工程学院</td><td>zhenghongguo@sjtu.edu.cn</td></tr>
<tr><th colspan="5">课程扩展信息 Extended Information</th></tr>
<tr><td>*课程简介
(中文)
Course Description</td><td colspan="4">（分段概述课程定位、教学目标、主要内容、先修课程等；不少于 200 字。）
本课程是材料学科的专业基础课，以动力学和晶体学为核心讲述显微组织演化的基础理论，培养学生在学术研究过程中自觉运用固态相变知识进行显微组织分析和预测的能力。
课程内容主要包括三个模块。第一模块为固态相变的一般特征，含传统和新型非晶、准晶和纳米晶材料的结构稳定性、相变分类和相界面现象；第二模块重点强调驱动力作用下显微组织随时间和温度的变化过程，以及利用微积分知识进行数学建模。以固态相变为典型例子，有意识地增加扩散、界面和位错运动的知识要点。这部分授课内容含大量近现代研究成果(尤其是国内学者近二十年的重大创新成果)，如形核的软模理论、动力学总成的时间锥理论、解析相变模型、相场理论、Landau 热力学、纳米材料结构稳定性的尺寸效应等；第三模块涉及晶体学理论，基于线性代数和晶体几何，涵盖所有类型相变的晶体学，如不变平面应变、不变线应变和基于 O 点阵模型提出的奇异性判据。这样的授课安排，希望从总结本科阶段的知识开始，循序渐进深入以显微组织演化为核心的材料动力学和晶体学知识体系，并扩展到近代物理模型，使学生能对“动态进程”的理解更为扎实，并熟练运用数学知识于动力学和晶体学的量化规律研究。
为了更好地理解课程内容，选修学生至少需提前学过：材料科学基础(本科)、材料加工原理/热处理原理(本科)、材料热力学(本科/研究生)等课程。</td></tr>
<tr><td>*课程简介
（English）
Course Description</td><td colspan="4">This lecture refers to basic theory of microstructural evolution, but centers on the kinetic and crystallographic knowledge of solid state transformation with thermodynamics as the starting point, aiming at strengthening analysis and prediction capability of microstructure with principles of solid state transformations.
The main contents of the course include three modules. The first one provides an overview about solid state transformation, i.e., the microstructural stability of traditional bulk and novel amorphous, nanocrystalline and quisicrystalline materials, the classification of transformation and interfacial phenomenon; the second one is the core part of the lecture to cover essentials of kinetics with significant theoretical innovations recently (especially those from domestic scholars) as typical example. The view point from modern physics concerning the kinetics of microstructural evolution, including diffusion, interfacial migration, dislocation motion and</td></tr>
</table>

	phase transformation, are introduced with both physical concepts and mathematical modeling. They are modulus softening, time-cone, analytical model, phase field, Landau thermodynamic and size effect of nanocrystalline, etc.; the third one introduces crystallographic features of both diffusionless and diffusional transformations by algebra expression, with particular focus on quantitative expression of orientation relationship and interfacial structure by singular criteria, such as invariant plane strain, invariant line strain and energy cusp associated with structural matching. In general, the lecture focuses on the interpretation of physical nature with mathematic tools of microstructural evolution to strengthen students' understanding about kinetics and crystallography of material. The purpose aims to conduct students to the material design/application and to understand more in-depth studies. The students who select this lecture are assumed to have learned following courses at least: Fundamentals of Materials Science (undergraduate level), Principles of Materials Processing/Principles of Heat Treatment (undergraduate level) and Thermodynamics of Materials (undergraduate/graduate level).

*教学大纲(中文) Syllabus

（建议列表形式，各列内容：章节、主要内容、课时数、教学方式）

章节	主要内容	课时数	教学方式
课程概述(序言)	研究相变的目的；重要人物及进展；课程内容；前修课程要求；主要参考文献；考核方式；	1	课堂讲述
第一章 相变概述	母相的失稳与相变(母相失稳的热力学条件，过渡相与平衡相的形成)；典型扩散相变的特征(脱溶沉淀，共析分解，块状相变，调幅分解，奥氏体化)；马氏体相变的特征(马氏体相变的晶体学特征，马氏体相变能量学，形状记忆效应)；新型材料的相变(非晶的晶化，纳米材料的相变，准晶的热稳定性)；	5	课堂讲述
第二章 相变的分类与特征	相变按热力学分类(体系的热力学函数，一级相变与高级相变，相变的热力学关系式)；一级相变按原子移动方式分类(重构(扩散)型和位移型(无扩散型)相变，重构型相变的分类和特征，位移型相变的分类和特征)；一级相变按动力学分类(稳定和不稳定的成分-自由能曲线，Gibbs 定义的两类相变)；一级相变的简明分类；	3	课堂讲述
第三章 界面现象	两相界面结构相(界面的错配度模型，共格的丧失，滑移型界面)；界面能的计算(共格界面能的离散点阵模型，共格界面能的连续模型，半共格界面能的结构分量，非共格界面的界面能，界面能的各向异性)；界面的曲率效应(Gibbs-Thompson 效应，沉淀相熟化，其它显微组织的熟化)；	6	课堂讲述
第四章相变动力学基础	不可逆过程热力学(建构动力学理论的热力学基础，熵和熵产，线性不可逆过程热力学，约束条件下广延量的力-流关系)；相变的共同特征(序参量，自由能变化与序参量的关系)；Landau 热力学与固态相变(二级相变的	5	课堂讲述

		Landau 热力学理论，Laudau 理论与一级相变，相变动力学方程的推导)；		
	第五章 调幅分解和有序化(含半节课的作业讲解)	均匀相变的共同特征(广义扩散方程，非均匀系统的自由能，弥散界面的结构和能量)；均匀相变的动力学理论(扩散的势函数，Cahn-Hilliard 和 Allen-Cahn 方程，数值模拟和相场方法)；相变波长和共格应变效应(临界波长和动力学波长，共格应变效应，广义化的 Cahn-Hilliard 方程)；	4	课堂讲述
	第六章 形核理论	均匀形核(经典形核理论，孕育期，弹性应变能效应，晶核的择优形状，溶质配分对形核率的影响，讨论)；非均匀形核(晶界形核，位错形核，其它类型的非均匀形核)；马氏体的形核理论(热起伏形核，马氏体的非均匀形核理论，马氏体形核的软模理论)；	6	课堂讲述
	第七章 新相生长	脱溶相的扩散生长(成分无变化的新相生长，涉及长程扩散的相变，片状和针状魏氏组织的生长机制，两相共格程度对生长速率的影响)；共析分解(溶质原子通过母相扩散(体扩散)，溶质原子通过生长界面扩散(界面反应))；马氏体的生长(界面运动动力学理论，马氏体生长引起的应力场)；	6	课堂讲述
	第八章 动力学的形式理论	等温相变动力学(相变动力学的一般规律，界面反应控制生长的等温相变动力学，长程扩散控制生长的等温相变动力学，等温转变动力学曲线)；变温相变动力学(变温效应，叠加原理，解析相变模型)；马氏体相变动力学(等温马氏体相变动力学，变温马氏体相变动力学)；	6	课堂讲述
	第九章 相变晶体学（含半节课的作业讲解)	矢量与矩阵(定义，不变线矢和不变法矢，均匀形变，机械孪生，坐标系的线性变换，点阵对应，不变平面应变)；马氏体相变晶体学(点阵形变，通过附加点阵不变形变获得不畸变平面，通过附加点阵刚性旋转获得不变平面，晶体学问题的代数分析思路，晶体学模型的进一步说明，马氏体与母相的界面特征)；扩散型相变的晶体学理论(不变线应变理论，O 点阵理论，奇异性判据)；	6	课堂讲述
*教学大纲（English）Syllabus	（须与中文一致，翻译请力求信达雅。）			
	Chapter	Main Contents	Hour(s)	Manner
	Preface	Purpose of phase transformation research; Critical progress and related scientists; Course	1	Lecture in classroom

		contents; Course prerequisites; Main references; Examinations;		
	Chapter 1 An Overview	Instability of parent phase and transformation (Thermodynamic criterion of instability, Formation of transitional and equilibrium phase); Characteristics of Typical diffusional transformation(Precipitation, Eutectoid decomposition, Massive transformation, Spinodal decomposition, Austenitization); Characteristics of martensitic transformation (Crystallographic features of martensitic transformation, Energetics of martensitic transformation, Shape memory effect); Phase transformation in novel materials (Crystallization of amorphous alloys, Phase transformation in nanocrystalline materials, Thermal stability of quasi-crystalline materials);	5	ibid
	Chapter 2 Classification and Characteristics of Phase Transformation	Classification according to thermodynamics (Thermodynamical function of assembly, First- and higher-order transformations, Thermodynamic description of phase transformation); Classification of first-order transformation (Reconstructive (diffusional) and displacive (diffusionless) transformation, Classification and characteristics of reconstructive transformation, Classification and characteristics of displacive transformation); Classification according to kinetics (Stable and unstable free-energy curve, Gibbs's two type of transformation); Concise classification of first order transformation;	3	ibid
	Chapter 3 Interfacial Phenomenon	Interfacial structure (Misfit model of interface, Coherency Loss, Glissile interface); Interfacial energy (Discrete-lattice model of coherent interface, Continuous model of coherent interface, Structural component of semi-coherent interface, Energy of incoherent interface, Anisotropy of interfacial energy); Curvature effect of interface (Gibbs-Thompson effect, Ripening of precipitates, Ripening of other microstructures);	6	ibid
	Chapter 4 Kinetic Fundamentals of Transformation	Irreversible thermodynamics (Thermodynamic fundamental of kinetic theory, Entropy and entropy production, Linear irreversible thermodynamics, Force-flux relations when extensive quantities are constrained); Common features of transformation (Order-parameter, Free-energy and order-parameters relations); Landau theory and solid state transformation (Landau theory and second-order transformation, Landau theory and first-order transformation, Derivation of kinetic equation);	5	ibid
		General features of homogeneous transformation (Generalized diffusion equation, Free-energy of an inhomogeneous		

	Chapter 5 Spinodal Decomposition and Order-Disorder Transformation (including recitation)	system, Structure and energy of diffuse interfaces); Kinetics of homogeneous transformation (Diffusion potential for transformation, Cahn-Hilliard and Allen-Cahn equations, Numerical simulation an phase-field method); Wavelength and coherent-strain effect (Critical and kinetic wavelengths, Coherent-strain effect, Generalization of Cahn-Hilliard equation);	4	ibid
	Chapter 6 Nucleation	Homogeneous nucleation (Classical theory of nucleation, Incubation period, Effect of elastic strain energy, Nucleus shape of minimum energy, Effect of composition partitioning on the nucleation rate, Discussion); Heterogeneous nucleation (Nucleation on grain boundaries, edges and corners, Nucleation on dislocations, Nucleation on other crystalline defects); Martensitic nucleation (Nucleation by thermal fluctuation, Heterogeneous nucleation, Nucleation by modulus softening);	6	ibid
	Chapter 7 Growth	Growth process of precipitates (Growth without change of composition, Growth involving long-range diffusion, Growth of plate and acicular widmanstatten structure, Role of interface structure in growth process); Eutectoid transformation (Diffusion-controlled growth, Growth controlled by process at the interface); Growth of martensite (Dynamics of martensitic interfaces, Soliton model of interfacial movement);	6	ibid
	Chapter 8 Former Theory of Transformation Kinetics	Analysis of isothermal transformation curves (General feature of isothermal transformation, Transformations without change of composition, Transformations with parabolic growth laws, Temperature-time-transformation diagram); Effect of temperature: non-isothermal transformation (Effect of continuous cooling, Addictive rule); Kinetics of martensitic transformation (Isothermal martensitic transformation, Athermal martensitic transformation);	6	ibid
	Chapter 9 Crystallography of Transformation	Vector and matrix (Definition, Invariant line and invariant normal, Homogeneous deformation, Deformation twinning, Linear transformation of the coordinative system, Lattice correspondence, Invariant plane strain); Crystallography of martensitic transformation (Lattice deformation, Undistorted plane by application of additional lattice invariant deformation, Invariant plane by addition of rigid-body rotation, Algebra analysis of the crystallography, Further aspect of the crystallographic model, Interfacial feature of martensite); Crystallography pf diffusional transformation (Theory of invariant line strain, Theory of O-lattice, Singular Criterion);	6	ibid

<table>
<tr><td>*课程要求
（中文）
Requirements</td><td>对学生的评价将基于四个部分: 1. 基于授课内容进行扩展性阅读和知识整理，在上半学期内完成 1 个专题读书报告(3000 字以上，题目范围由授课教师列出，学生选择一个专题进行文献阅读和综述) (20%)；2. 完成 2 次课后作业，每次 4 题 (30%)；3. 实行开卷夜考，在 12 小时内完成 4 道题目的解答，根据学生的答题质量排名 (30%)；4. 在课程结束后的一个月内(一般在夏季学期)学生要完成 1 篇与本课程及即将从事的研究方向紧密结合的文献评述(不是综述，不少于 5000 字) (20%)。最终根据学生在读书报告、家庭作业、夜考和文献评述的综合表现给予期末成绩。</td></tr>
<tr><td>*课程要求
（English）
Requirements</td><td>（须与中文一致，翻译请力求信达雅。）
The course grading is based on different weight among four parts with each should be finished before deadline according to teacher’s indications: a specific reading report (at least 3000 Chinese characters) within assigned topics (20%); Twice homework problems with each four (30%); Final examination with open book manner at night (30%); Literature review (at least 5000 Chinese characters) connecting course contents with research direction (20%).</td></tr>
<tr><td>课程资源
（中文）
Resources</td><td>（教材、教参、网站资料等。）
教材
郭正洪，固态相变动力学及晶体学，上海交通大学出版社，2019；
主要的参考资料(学生任选一本)：
1. 徐祖耀主编，材料相变，高等教育出版社，2013；
2. 冯端等，金属物理学(第二卷)：相变，科学出版社，1990；
3. J. W. Christian, The Theory of Transformations in Metals and Alloys, Fourth Eds., Pergamon Press, Oxford, 2002；
4. D. A. Porter, K. E. Easterling and M. Y. Sherif, Phase Transformations in Metals and Alloys, Third Eds., Chapman&Hall, London, 2008;
5. R. W. Balluffi, S. M. Allen and W. C. Carter. Kinetics of Materials. New York, NY: John Wiley & Sons, 2005.
另外，每章将推荐经典的研究文献至少三篇，要求学生从阅读原文着手体会科学思想的发展过程。</td></tr>
<tr><td>课程资源
（English）
Resources</td><td>（须与中文一致，请力求信达雅。）
Textbook
Zhenghong Guo, Kinetics abd Crystallography of Solid State Transformations, Shanghai Jiao Tong University Press,, Shanghai, 2019
Main References (Optional)：
1. T.Y. Hsu (Xu Zuyao)，Phase Transformations in Materials, High Education Press, Beijing, 2013;
2. Duan Feng, Physical Metallurgy (Vol. 2)：Phase Transformation, Science Press, Beijing, 1990；
3. J. W. Christian, The Theory of Transformations in Metals and Alloys, Fourth Eds., Pergamon Press, Oxford, 2002；
4. D. A. Porter, K. E. Easterling and M. Y. Sherif, Phase Transformations in Metals and Alloys, Third Eds., Chapman&Hall, London, 2008;
5. R. W. Balluffi, S. M. Allen and W. C. Carter. Kinetics of Materials. New York, NY: John Wiley & Sons, 2005.

In addition, at least three classical papers will be recommonded for each chapter, aiming at help students to understand the initiation and development of scientific thoughts.</td></tr>
<tr><td>备注
Note</td><td>本新开课程是根据学院教学委员会建议，对原先课程《动力学与固态相变》（MSE6401H）进行课程名称修改而形成。</td></tr>
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