山东大学
SHANDONG UNIVERSITY

Introduction to Solid-State Theory
固体理论导引

李元，张晨

山东大学信息科学与工程学院

2024-2025学年第二学期

基础物理 II-2025

群号: 873537930

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课程简介

课程名称： 固体理论导引（Introduction to Solid-State Theory）

课号序号： sd012347B0-0

教学语言： 双语（英文课件 + 中/英文讲义 + 中文讲解）

考核形式： 考试（闭卷），期末成绩（50%）+ 平时成绩（50%）

上课时间： 1-2节/周一、7-8节/周四（1-16周）

上课地点： 振声苑 E305

任课教师： 李元 Email: yuan.li@sdu.edu.cn 办公室: N5 楼 207
张晨 Email: chenzhang@sdu.edu.cn 办公室: N5 楼 227-1

参考教材

李元, 张晨, 《基础物理II固体理论导引-讲义》. （主要参考教材）


基础物理 II 固体理论导引

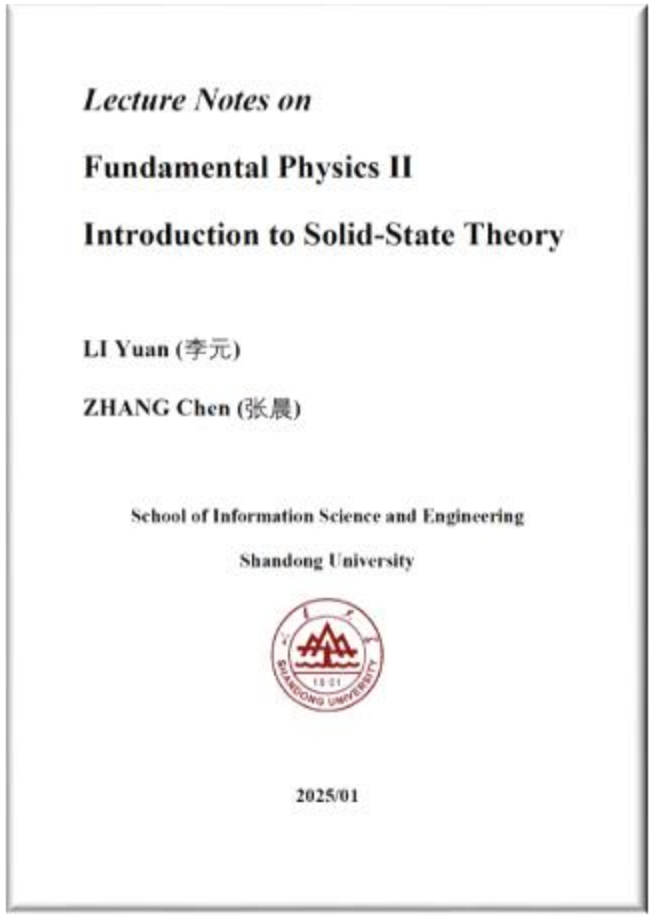
讲义

李元，张晨

信息科学与工程学院

山东大学

2025/01


Lecture Notes on

Fundamental Physics II

Introduction to Solid-State Theory

LI Yuan (李元)

ZHANG Chen (张晨)

School of Information Science and Engineering

Shandong University

2025/01

参考教材

[1] 黄昆, 韩汝琦, 固体物理学, 高等教育出版社 (1988).

[2] C. Kittel, *Introduction to Solid State Physics*, 8th Edition, John Wiley & Sons (2005).

[3] R. Hummel, *Electronic Properties of Materials*, 4th Edition, Springer (2011).

[4] 王矜奉, 固体物理教程, 山东大学出版社 (2013).

[5] 方俊鑫, 陆栋, 固体物理学(上下册), 上海科技出版社 (1980, 1981).

[6] 曾谨言, 量子力学(卷I), 科学出版社 (2018).

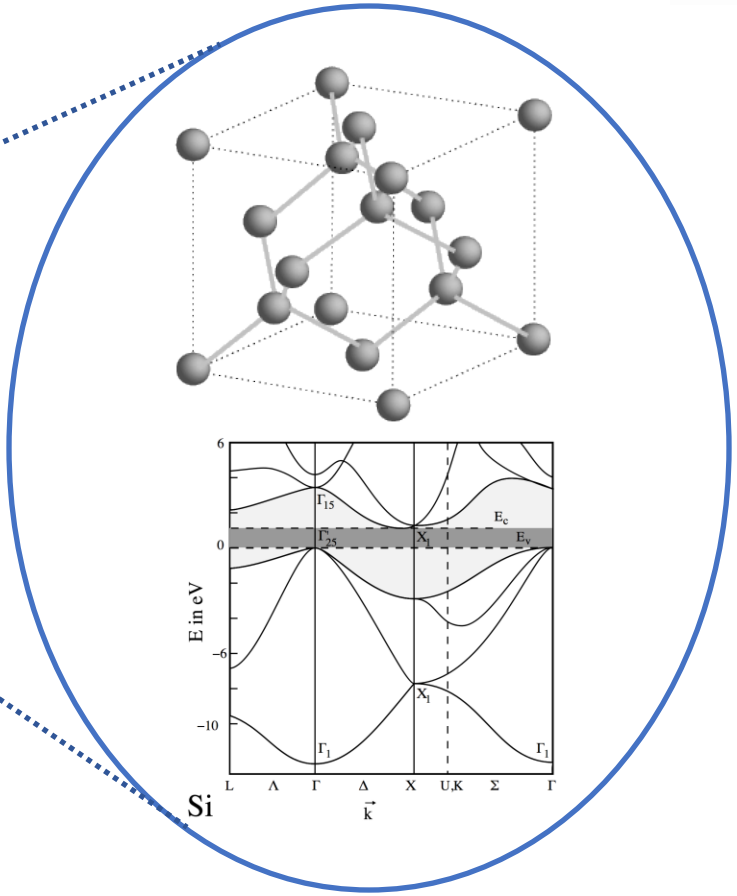
Objectives

- ❖ What is Solid-State Physics?
- ❖ Why is Solid-State Physics important?
- ❖ Our plan for this course.

What is Solid-State Physics?

- Electrical
- Optical
- Thermal
- Mechanical
- ……

(Silicon)



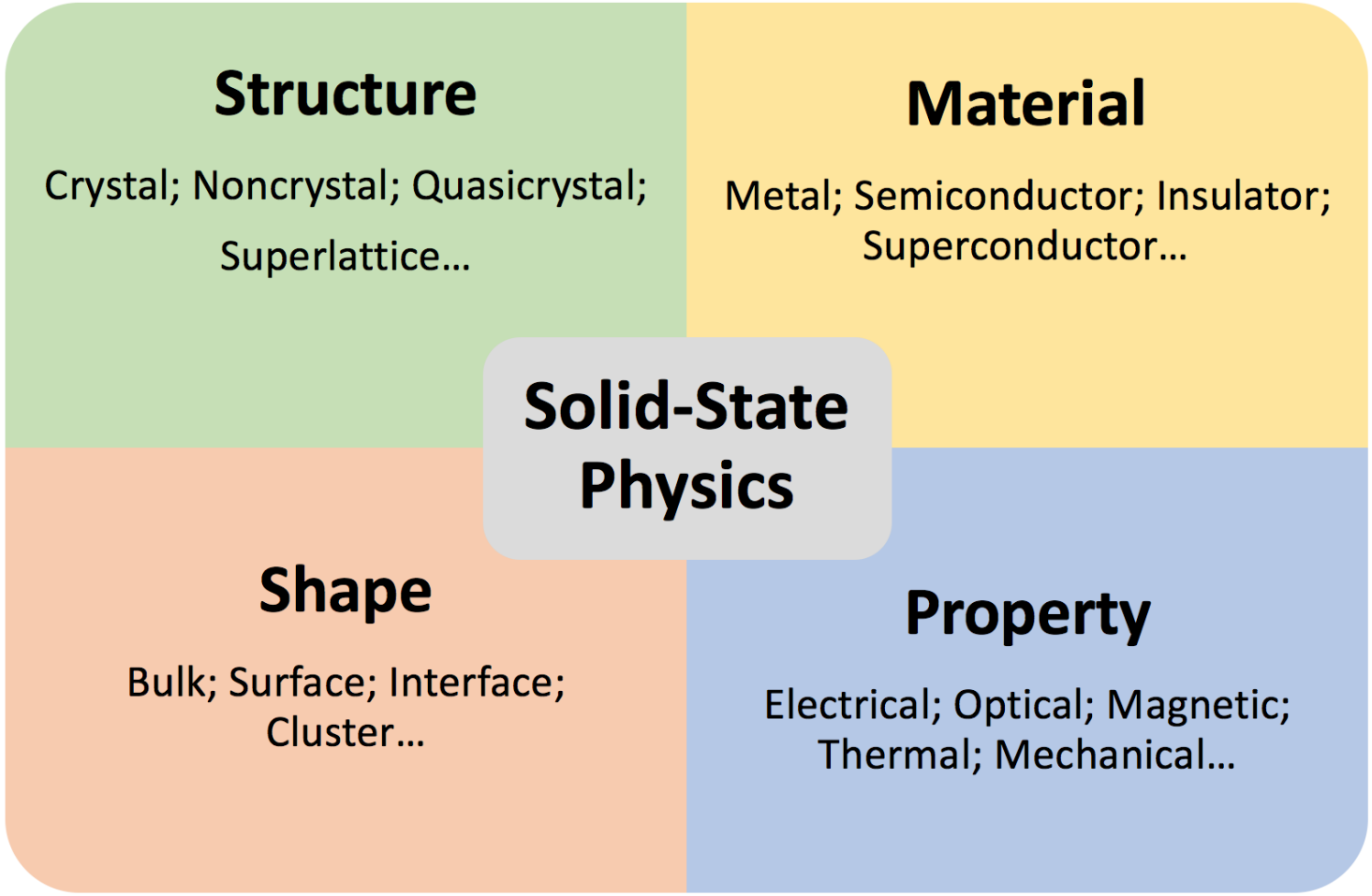
Large-Scale Properties

Atomic-Scale Properties

What is Solid-State Physics?

Solid-State Physics (固体物理) studies how the **large-scale properties** of solid materials result from their **atomic-scale properties**!

What is Solid-State Physics?



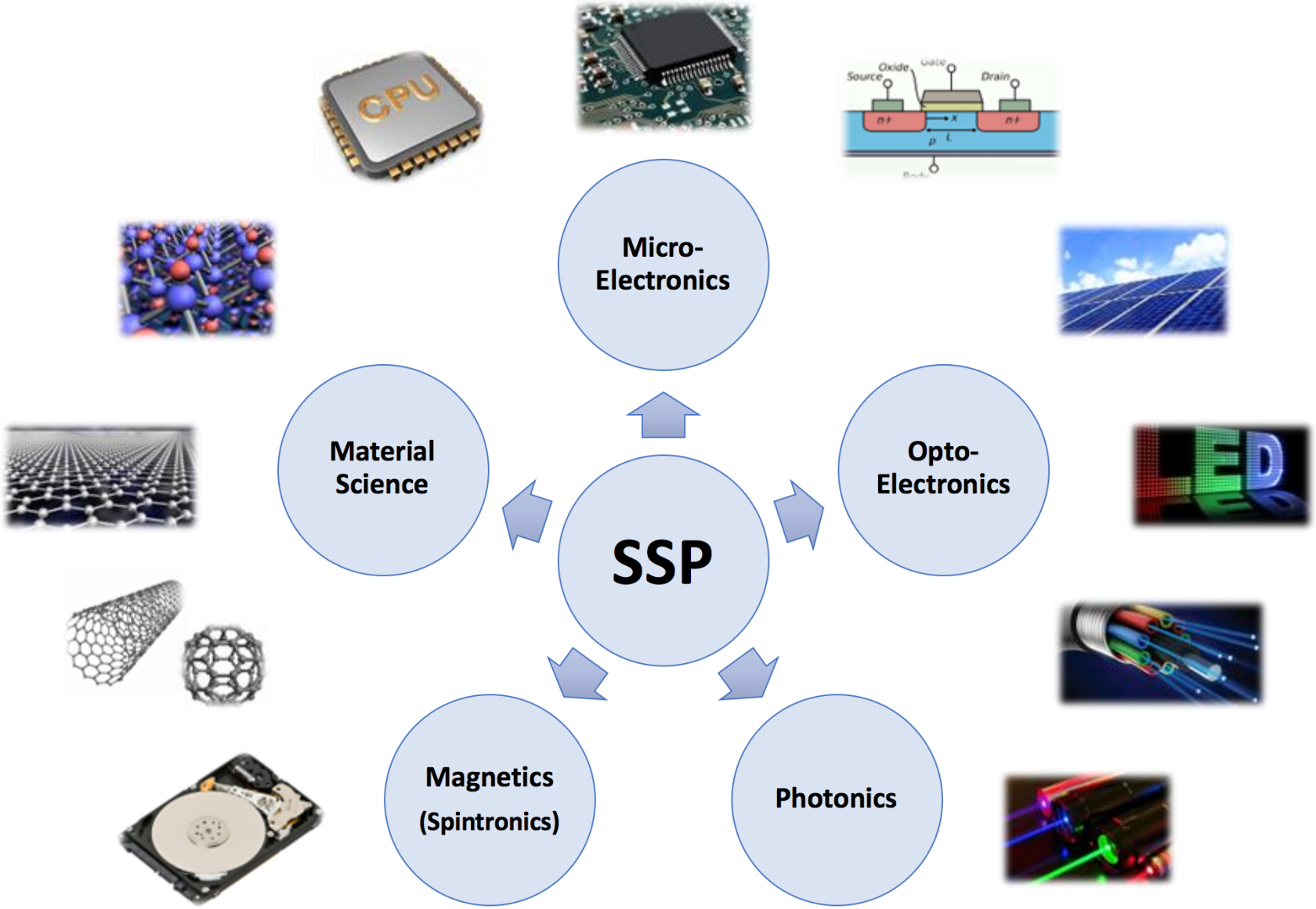
SSP always tries to understand a physical phenomenon from the **microscopic point of view**!

Why is Solid-State Physics important?

Solid-State Physics lays the foundation of

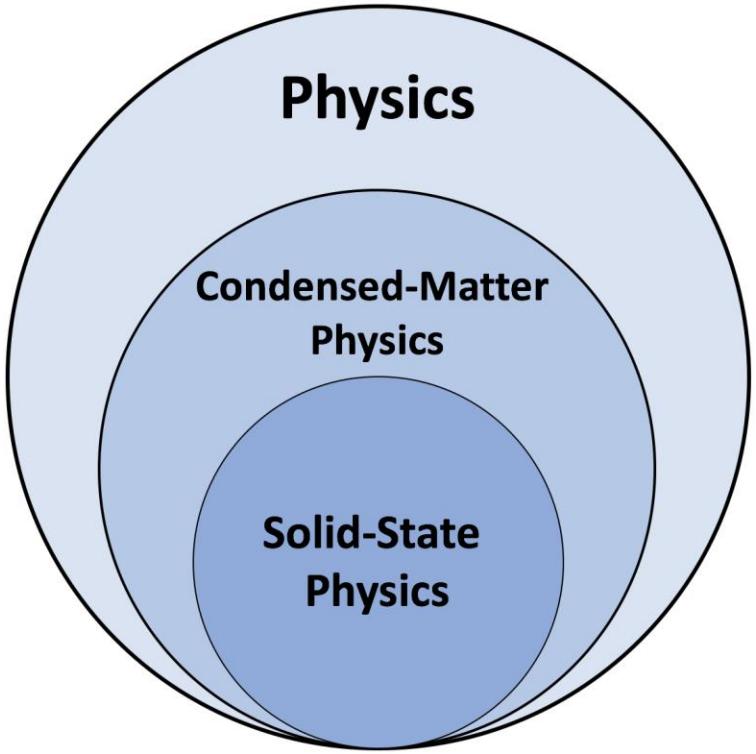
Information Science and Technology!

Why is Solid-State Physics important?



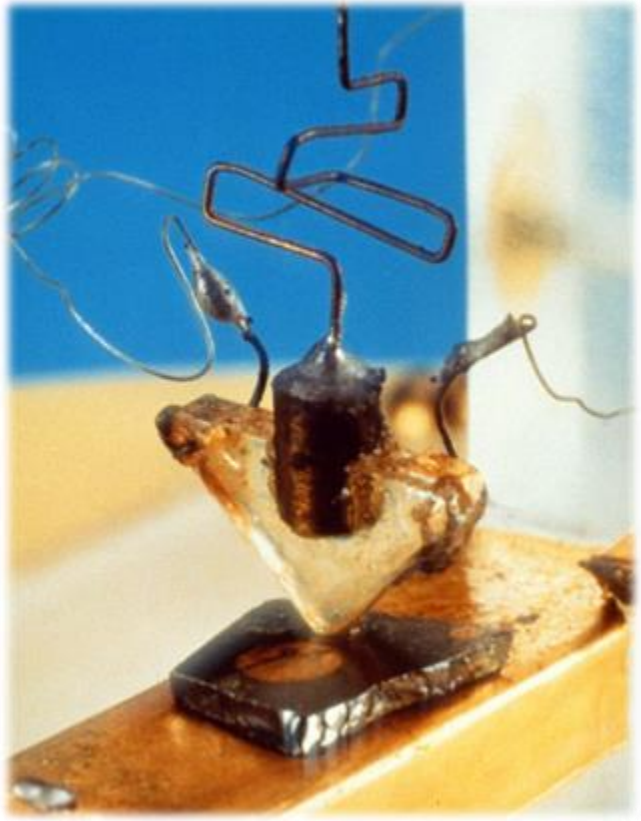
Why is Solid-State Physics important?

Since 1950, **21 Nobel Prizes in Physics** (about 30%) and **5 Nobel Prizes in Chemistry** have been awarded to scientists for their discoveries associated with **Solid-State Physics or Condensed-Matter Physics** (an expansion of Solid-State Physics).

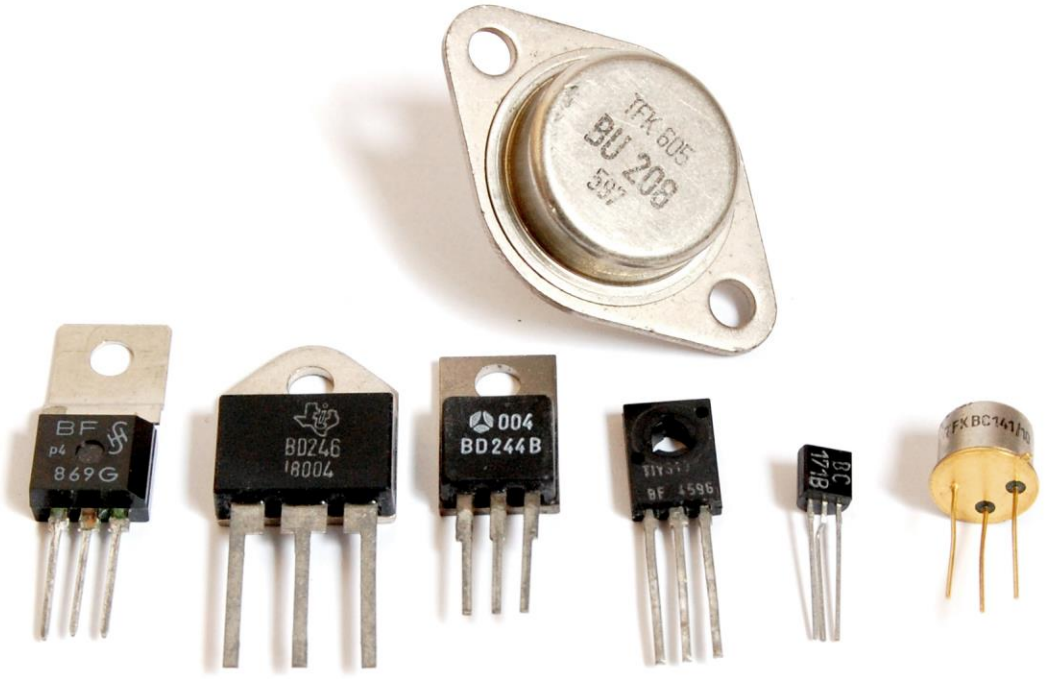


Why is Solid-State Physics important?

- **Transistor (晶体管)**



The First Solid-State Transistor Invented by
Bardeen, **Brattain**, and **Shockley** in December 1947



Why is Solid-State Physics important?

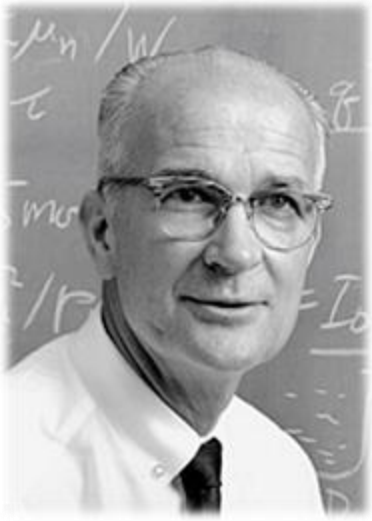
➢ Transistor (晶体管)

Nobel Prize in Physics 1956

Co-inventors of Transistor

John Bardeen*
(1908-1991)
American Physicist

Walter Brattain
(1902-1987)
American Physicist



William Shockley
(1910-1989)
American Physicist

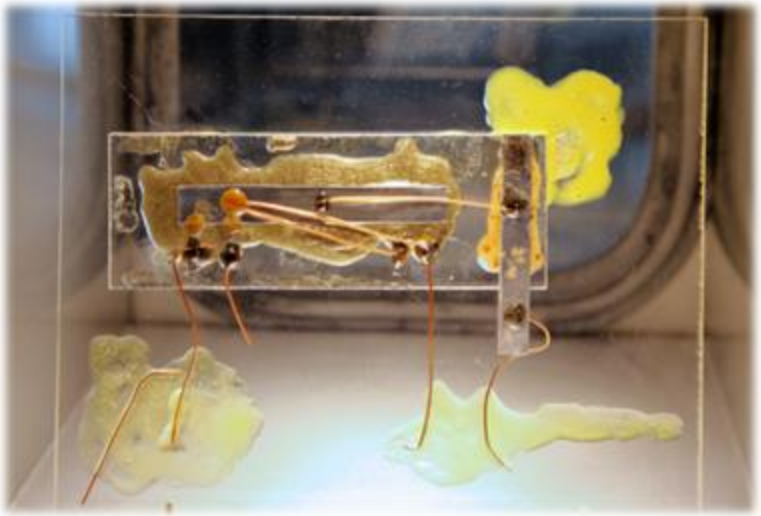
Herbert Matare
(1912-2011)
German Physicist

Heinrich Welker
(1912-1981)
German Physicist

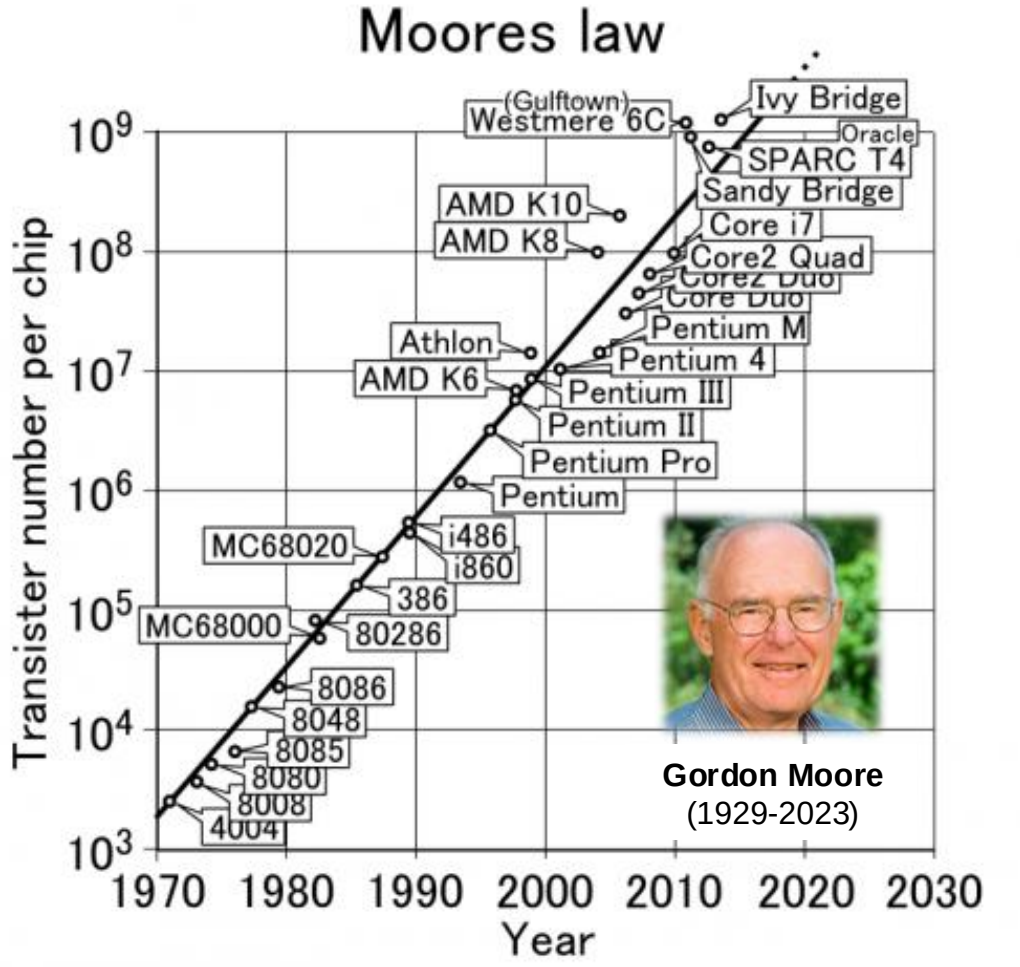
*John Bardeen was also one of the three winners of Nobel Prize in Physics in 1972 for their BCS (initial of Bardeen, Cooper, and Schrieffer) theory of superconductivity.

Why is Solid-State Physics important?

- **Integrated Circuit (集成电路)**



Replica of the First Integrated Circuit
Invented by **Jack Kilby** in 1958

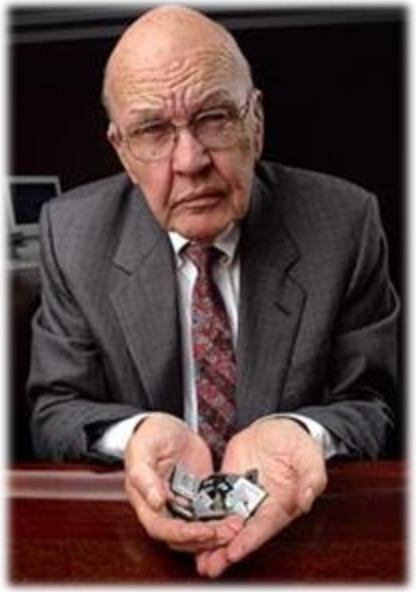


Why is Solid-State Physics important?

➢ Integrated Circuit (集成电路)

Nobel Prize in Physics 2000

Co-inventor of Integrated Circuit



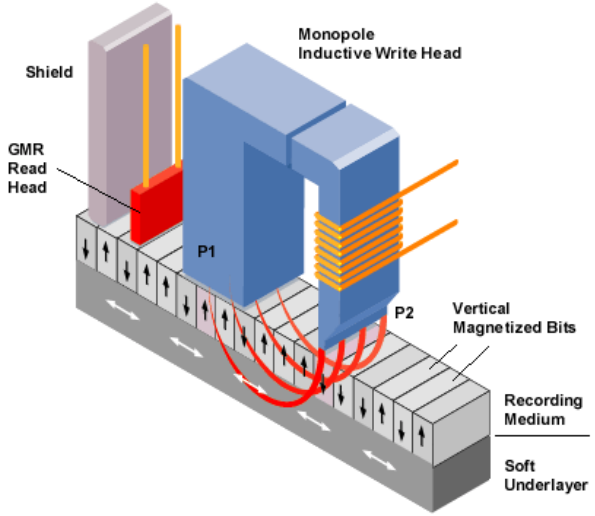
Jack Kilby
(1923-2005)
American Electrical Engineer

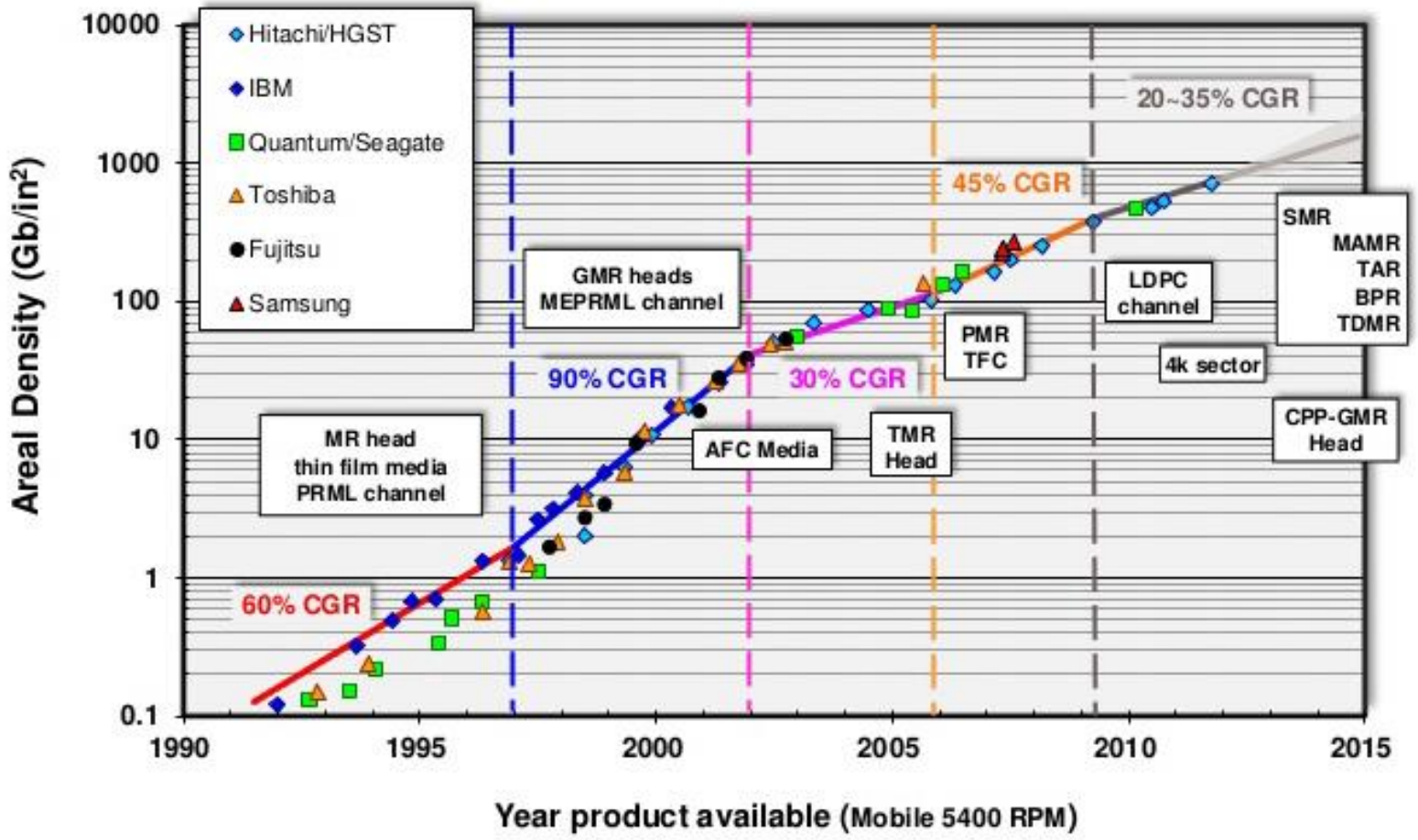
Robert Noyce
(1927-1990)
American Physicist
Co-founder of Fairchild Semiconductor and Intel

Why is Solid-State Physics important?

➢ Giant Magnetoresistance (巨磁阻效应)

Applications in HDD Read Head

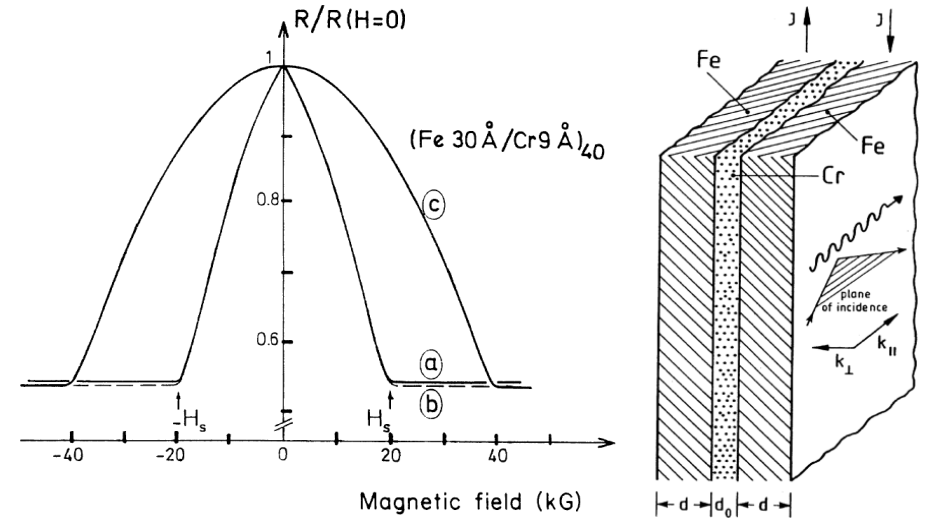


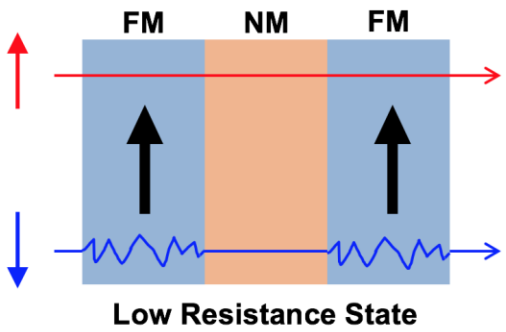


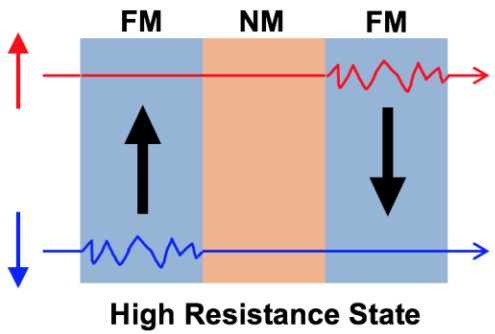
Why is Solid-State Physics important?

➢ Giant Magnetoresistance (巨磁阻效应)

MR ~ 50%







Nobel Prize in Physics 2007

Albert Fert
(1938-)
French Physicist

Peter Grünberg
(1939-2018)
German Physicist

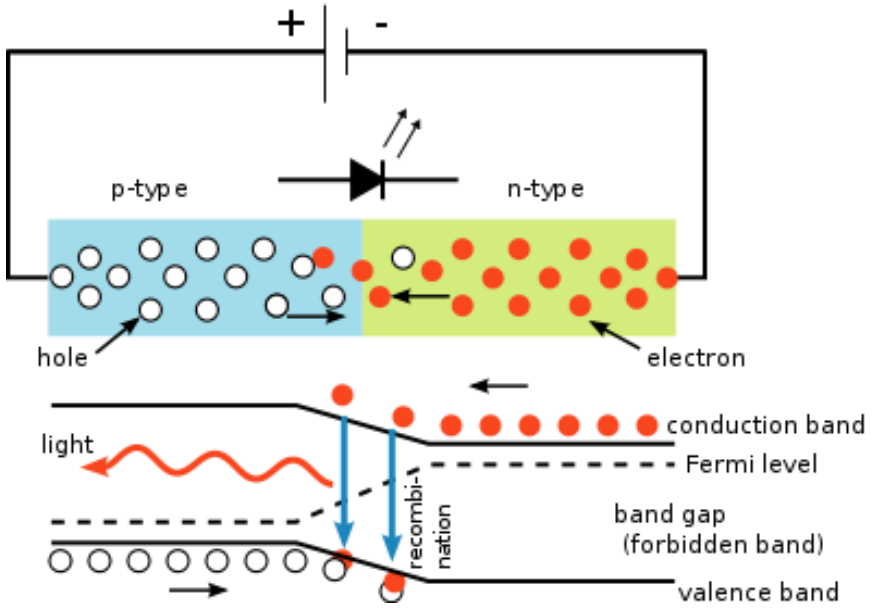
M. N. Baibich, J. M. Broto, **A. Fert** *et al.*, ***Phys. Rev. Lett.* 61, 2472 (1988).**

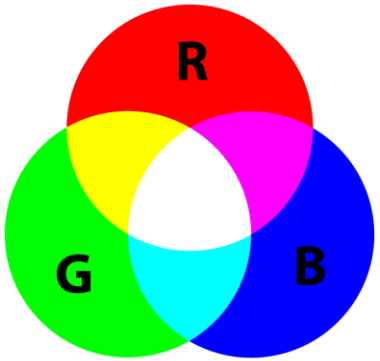
G. Binasch, **P. Grünberg**, F. Saurenbach, and W. Zinn, ***Phys. Rev. B* 39, 4828 (1989).**

Why is Solid-State Physics important?

➢ Blue Light-Emitting Diode (蓝光LED)

High-Brightness Blue LED





H. Amano, M. Kito, K. Hiramatsu, and **I. Akasaki**, ***Jpn. J. Appl. Phys.* 28, L2112 (1989).**

S. Nakamura, T. Mukai, and M. Senoh, ***Appl. Phys. Lett.* 64, 1687 (1994).**

Why is Solid-State Physics important?

- **Blue Light-Emitting Diode (蓝光LED)**

Nobel Prize in Physics 2014

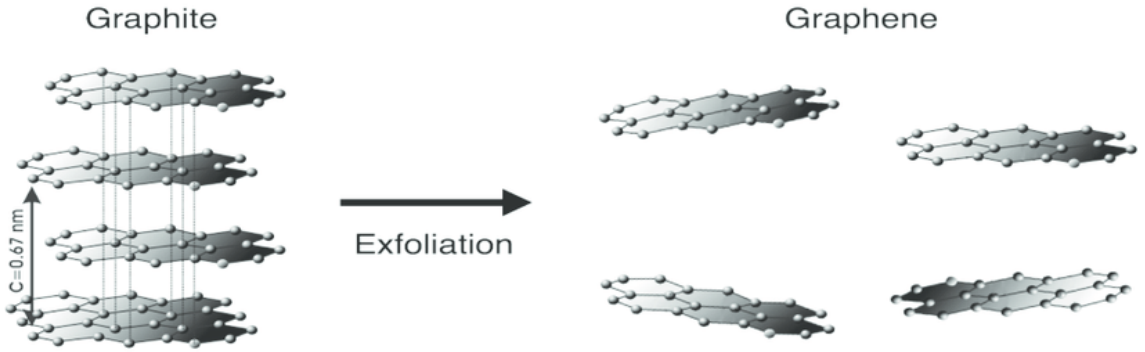
Isamu Akasaki 赤崎勇
(1929-2021)
Japanese Physicist

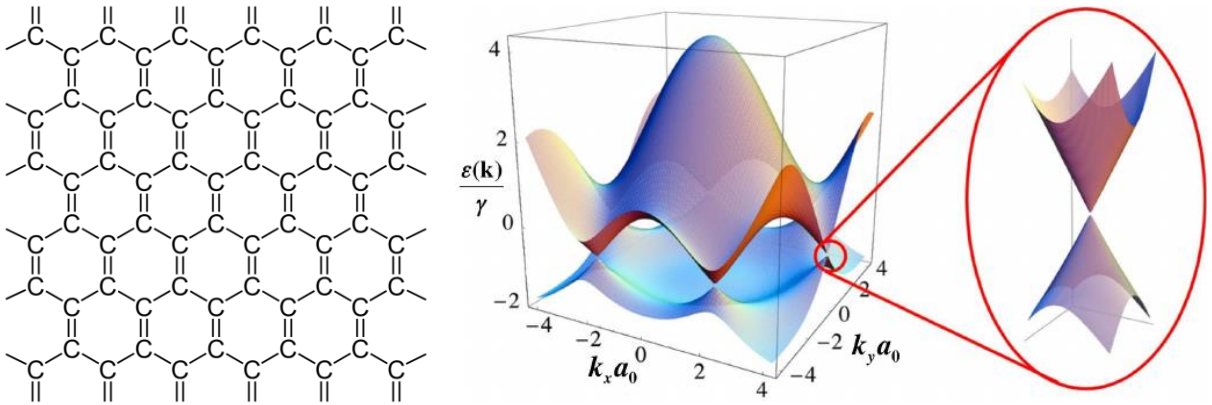
Hiroshi Amano 天野浩
(1960-)
Japanese Physicist

Shuji Nakamura 中村修二
(1954-)
Japanese-American Electronic Engineer

Why is Solid-State Physics important?

➢ Graphene (石墨烯)





Nobel Prize in Physics 2010

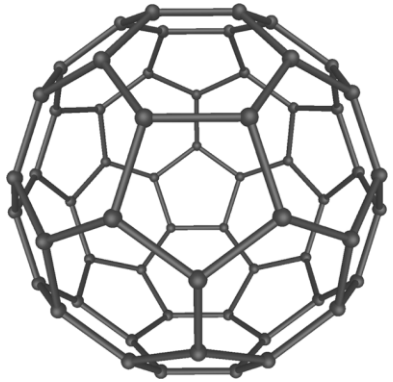
Andre Geim
(1958-)
Soviet-born Dutch-British Physicist

Konstantin Novoselov
(1974-)
Russian-British Physicist

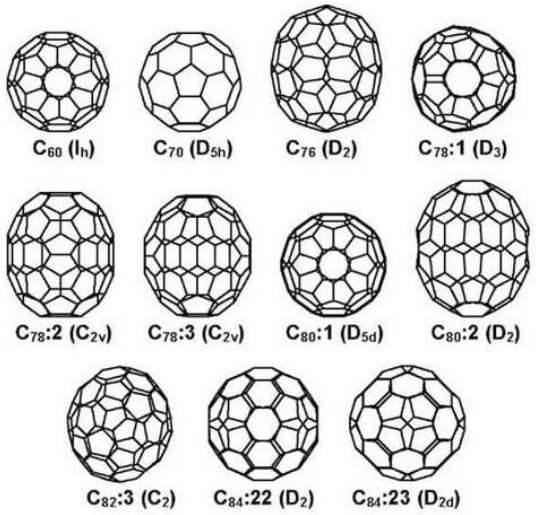
K. S. Novoselov, **A. K. Geim**, S. V. Morozov, *et al.*, ***Science*** **306, 666 (2004).**

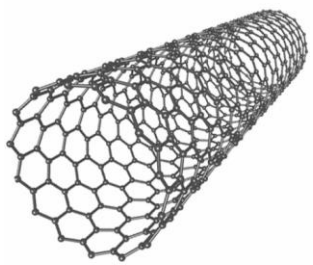
Why is Solid-State Physics important?

➢ Fullerene (富勒烯)



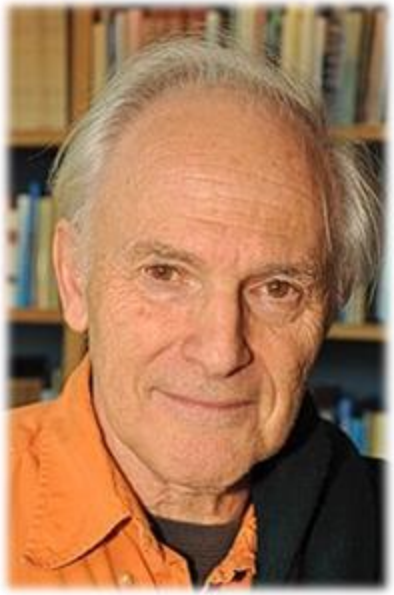
Buckminsterfullerene (C_{60})



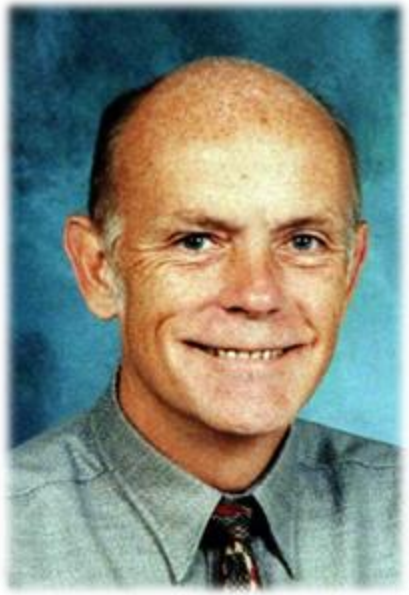


Nobel Prize in Chemistry 1996

Robert Curl
(1933-2022)
American Chemist



Harry Kroto
(1939-2016)
English Chemist



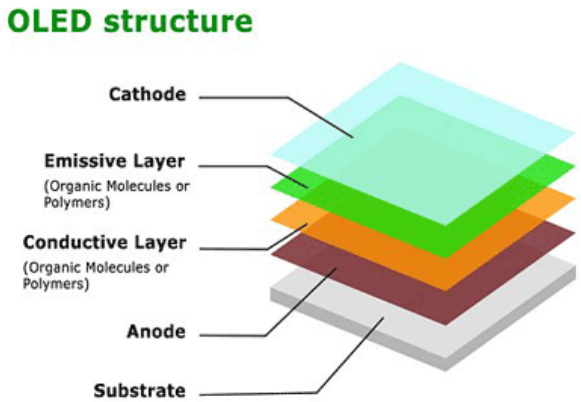
Richard Smalley
(1943-2005)
American Chemist

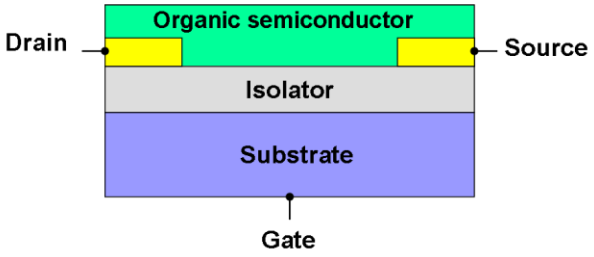
H. W. Kroto, J. R. Health, S. C. O'Brien, **R. F. Curl**, and **R. E. Smalley**, ***Nature*** **318, 162 (1985).**

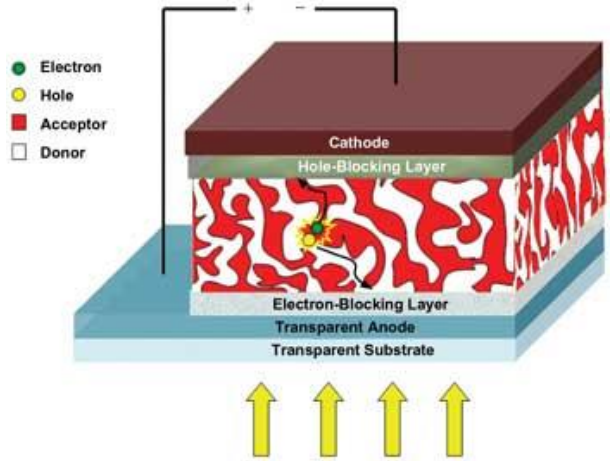
Why is Solid-State Physics important?

➢ Conductive Polymer (导电聚合物)

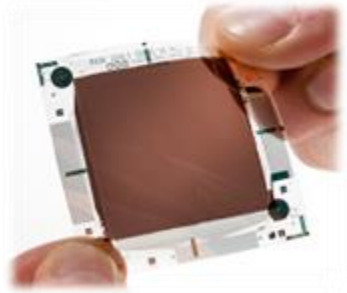
Organic Electronics and Optoelectronics







Organic Light-Emitting Diodes (OLED)

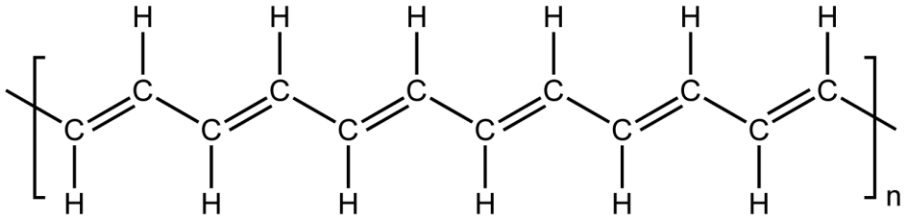


Organic Field-Effect Transistors (OFET)

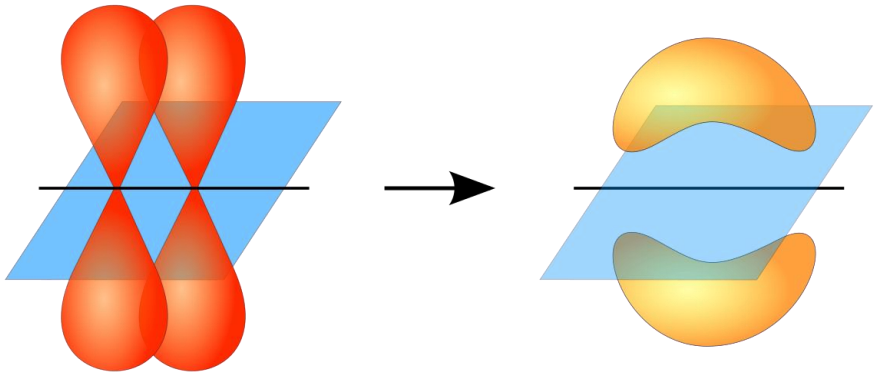
Organic Photovoltaics (OPV)

Why is Solid-State Physics important?

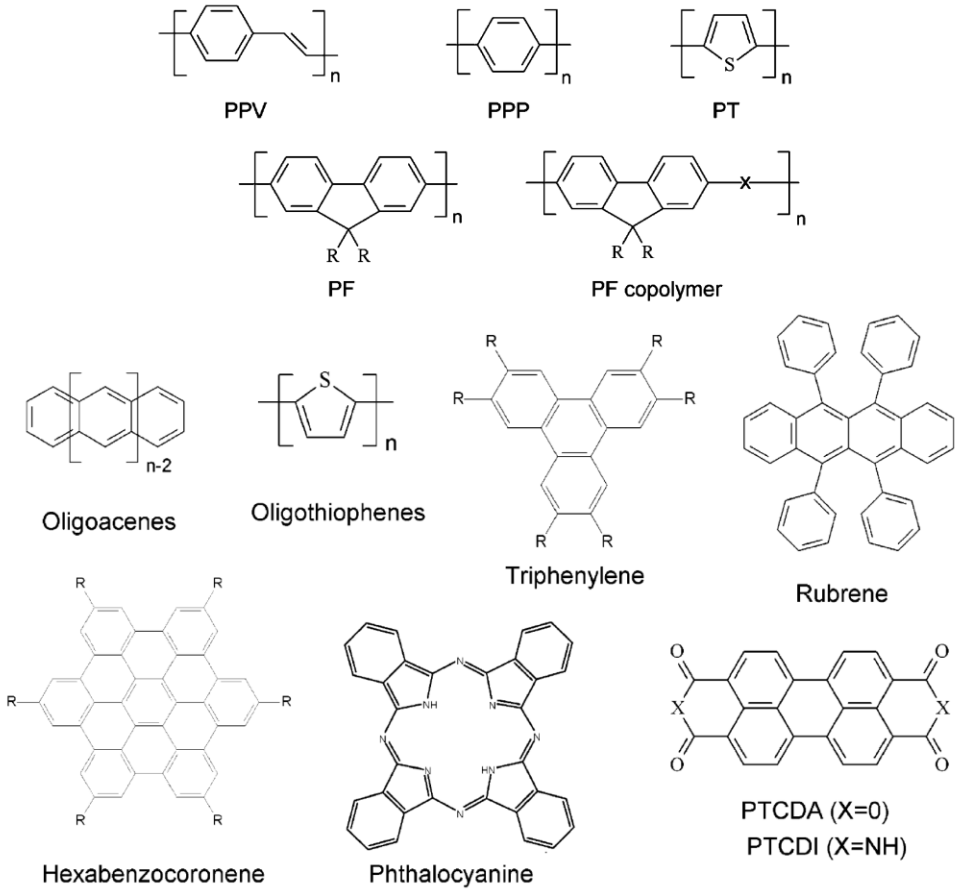
➢ Conductive Polymer (导电聚合物)



Polyacetylene



π-Conjugation



Organic Semiconductors

H. Shirakawa, E. J. Louis, **A. G. Macdiarmid**, C. K. Chiang, and **A. J. Heeger**, ***J. Chem. Soc., Chem. Commun.* 0, 578 (1977).**

Why is Solid-State Physics important?

- **Conductive Polymer (导电聚合物)**

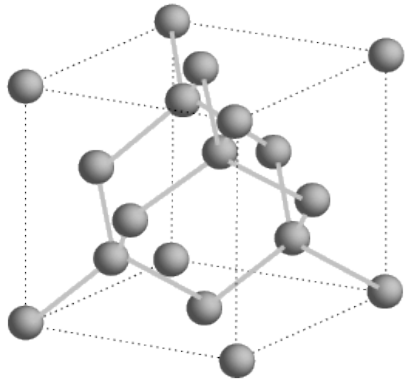
Nobel Prize in Chemistry 2000

Alan Heeger
(1936-)
American Physicist

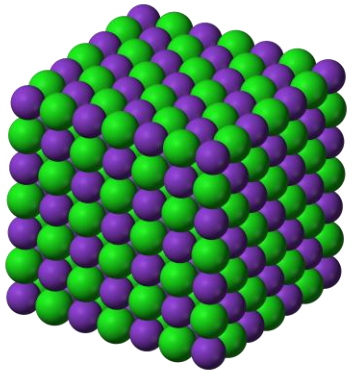
Alan MacDiarmid
(1927-2007)
New Zealand-American Chemist

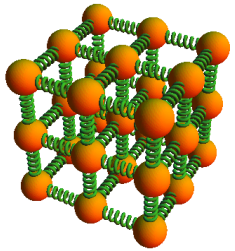
Hideki Shirakawa 白川英树
(1936-)
Japanese Chemist

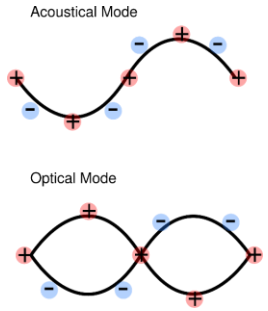
课程计划



Crystal Structure &Binding

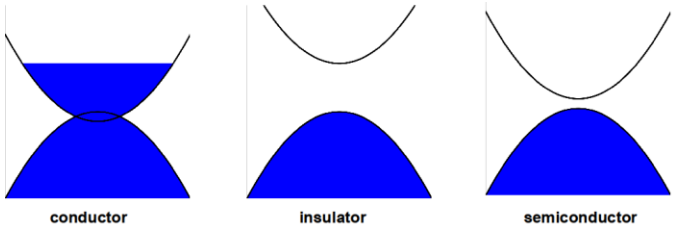






Lattice Vibrations (Phonons)

Electronic Structures (Band Theory)



Electron Motion in Solids

Optical Absorption &Excitations

Basic Magnetic Properties

Other Properties (optional)

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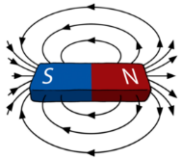
磁 

课程计划

➢ 课程划分

❑ Fundamental Theories (基础理论)

授课教师：李元

授课时间：第1-8周

❑ Properties and Applications (性质应用)

授课教师：张晨

授课时间：第9-16周

课程计划

➢ 仿真实验

❑ 仿真实验I：科学可视化

时间：第3-16周

形式：小组，作品创作

❑ 仿真实验II：计算模拟

时间：第8-16周

形式：个人，实验报告

课程计划

- **Fundamental Theories (基础理论)**

Chapter 1: Crystal Structure (晶体结构)

Chapter 2: Crystal Binding (晶体的结合)

Chapter 3: Lattice Vibrations and Phonons (晶格振动与声子)

Chapter 4: Electron Band Theory (电子能带理论)

Chapter 5: Metals and Semiconductors (金属与半导体)

课后作业

任选一项1950年以来与固体物理相关的诺贝尔奖或中国国家自然科学奖获奖成果，查阅其原始论文或相关资料，总结该成果对信息科学与技术所产生的影响（A4纸，1-2页）。

提交时间：3月3日之前

提交方式：手写（写明姓名学号）后拍照，通过课代表统一提交电子版