MIME262 – Properties of Materials in Electrical Engineering

- If you are signed up for ECSE 212, you **are** in the right place, **but** you need to drop ECSE 212 and register for MIME262.

- Course consists of lectures and tutorials

  Lectures – Mondays & Wednesdays, 4:35 PM – 5:55 PM, Trottier 0100

  In lecture, new material will be presented on the topics listed in the course schedule. The lecture does not supersede reading the book. Homework will be assigned and important announcements will be made.

  Tutorials –

  Group A, Wednesday, 8:35 AM – 9:25 AM, Trottier 0060

  Group B, Thursday, 2:35 PM – 3:25 PM, Trottier 2110

  Group C, Monday, 3:35 PM – 4:25 PM, Trottier 0070

  In tutorials, short reviews of lectures will be given, homework problems will be solved and group work on problems will be carried out. Quizzes will be given in the tutorials.

Textbook(s)

Required Text – Materials Science and Engineering – An Introduction (7th Edition), W.D. Callister, Jr. (Wiley, New York, 2006). ISBN 978-0-471-73696-7

This text will be used for every aspect of this course: assigned readings, lectures, tutorials, problem sets, and WebCT content.

Companion Text – Materials Science for Electrical and Electronic Engineers, I.P. Jones (Oxford Press, Oxford, 2001). ISBN 0-19-856294-2

This is a recommended text and will be used to supplement the required text for lectures, problem sets and WebCT content. It will be placed on reserve in the Schulich Library.

There are many other good introductory materials science and engineering textbooks available in the Schulich Library.

WebCT and Wiley Website

Please check the course's WebCT site frequently for announcements. WebCT will be used for all electronic correspondence. In the event you need to email your instructor, use the mail function in WebCT. Expect a 24 hour turnaround on weekdays and a 48 hour turnaround on weekends.

During weeks where there will be a WebCT quiz due on Friday at 5 PM, the latest that the quiz will be posted online will be Thursday morning.

Text Website: http://www.wiley.com/college/callister

- Additional Chapters (Chapters 19-23)
- Complete solutions to selected problems
- Links to other web resources
- Extended learning objectives
- Self-assessment exercises

Course Evaluation

For most of the course, we will alternate between WebCT quizzes one week and quizzes in the tutorial sections the next. WebCT quizzes will be due on Fridays by 5 PM. The tutorial quizzes will be given Wednesday through Monday (i.e. the week indicated on the calendar indicates that quizzes will start that Wednesday for group A and finish with Group C on the following Monday).

Two exams will be given, a mid-term on February 26th and the final exam. These will be worth 70% of the total grade.

Breakdown of marks

WebCT Quizzes	10%
Tutorial Quizzes^	20%
Mid-Term Exam*	30%
Final Exam	40%

^Take the quiz in your assigned tutorial.

***Make-ups given only for emergencies.**

***Discuss potential conflicts beforehand.**

Homework?

- Selected problems from Callister are worked out on the Wiley website. You should study and understand these.
- Additional questions and problems will be assigned from Callister (announced in lecture and posted on WebCT).
- Questions and problems NOT from Callister may be periodically posted to WebCT.

When do we do the homework? Is it graded?

- You should work on the homework outside of class.
- Also, selected problems will be solved in tutorial sections and you will work on homework and other problems in the tutorials.
- Homework is NOT graded.
- Solution sets will eventually be posted on WebCT.

Instructors and Teaching Assistants

Professor Richard R. Chromik
Wong Building, Rm. 2100
Ph: 398-5686
Email: Please use WebCT
Office hours: TBA and by appt.

Mister Arya Fatehi
Wong Building, Rm. 2330
Ph: 398-4755 ext 09511
Email: Contact via WebCT or use arya.fatehi@mail.mcgill.ca
Office hours: TBA and by appt.

Mister Hashem Mousavi
Wong Building, Rm. 3M040 (Mezzanine level above the MMPC lab)
Ph: 398-4755 ext 09521
Email: Contact via WebCT or use hashem.mousavi@mail.mcgill.ca
Office hours: TBA and by appt.

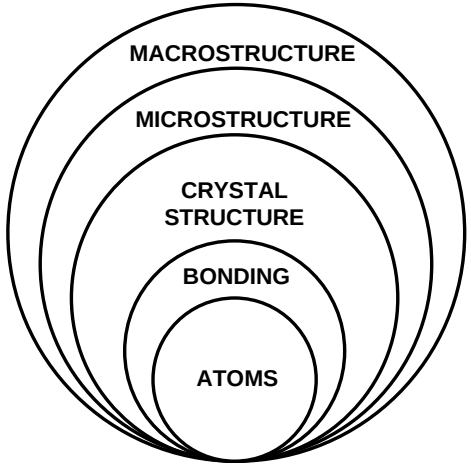
Why are you here?

Electrical Engineering

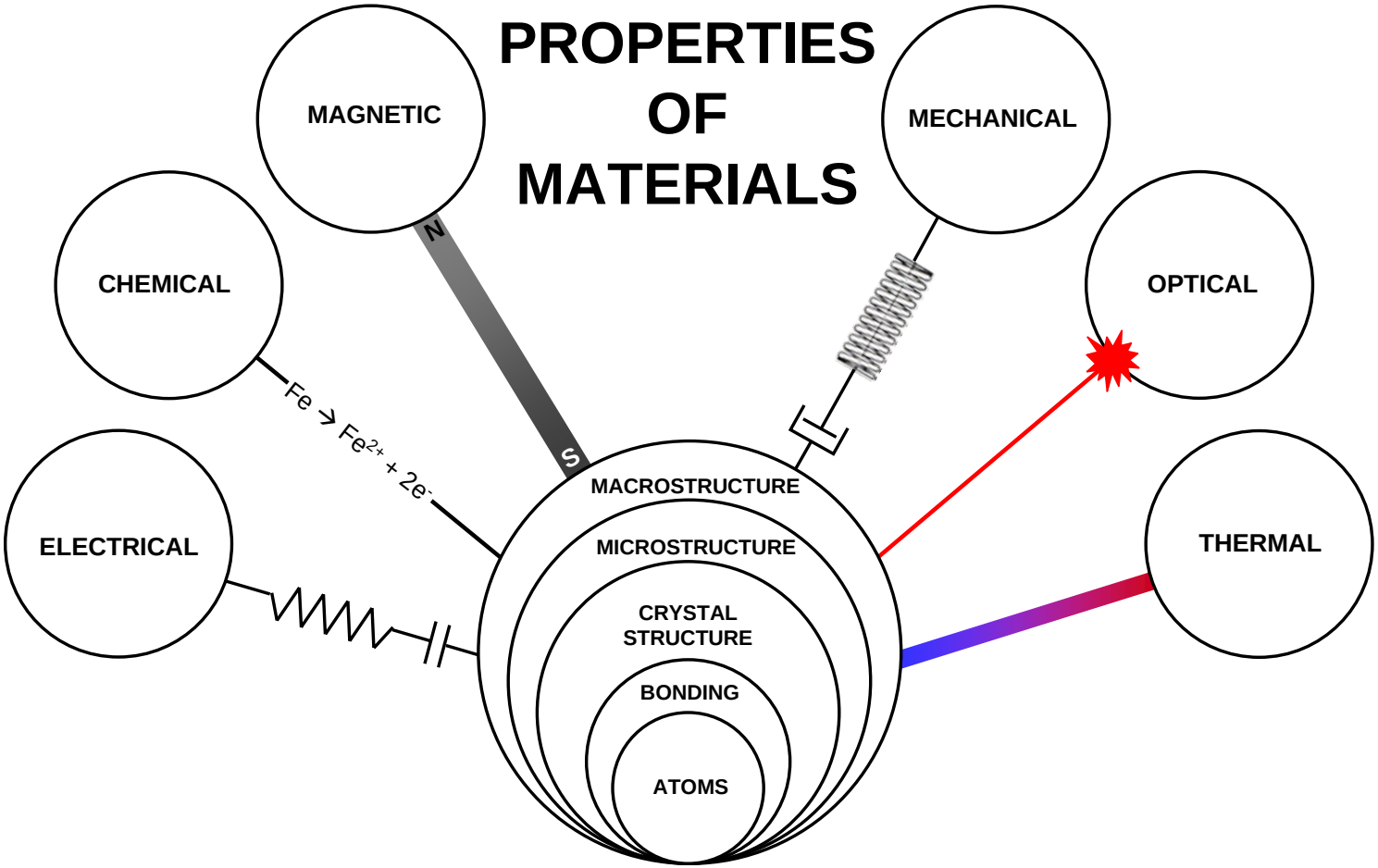
- Design and develop new devices for cutting edge applications
  - Computers
  - Communications
  - Complex control systems

- Lastest buzz words
  - *Quantum computing*
  - *Nano-electronics*
  - *Nano-optics*
  - *MEMS and NEMS*

Devices are built with REAL materials. They also require some interface with the outside world, i.e. PACKAGING (more materials).

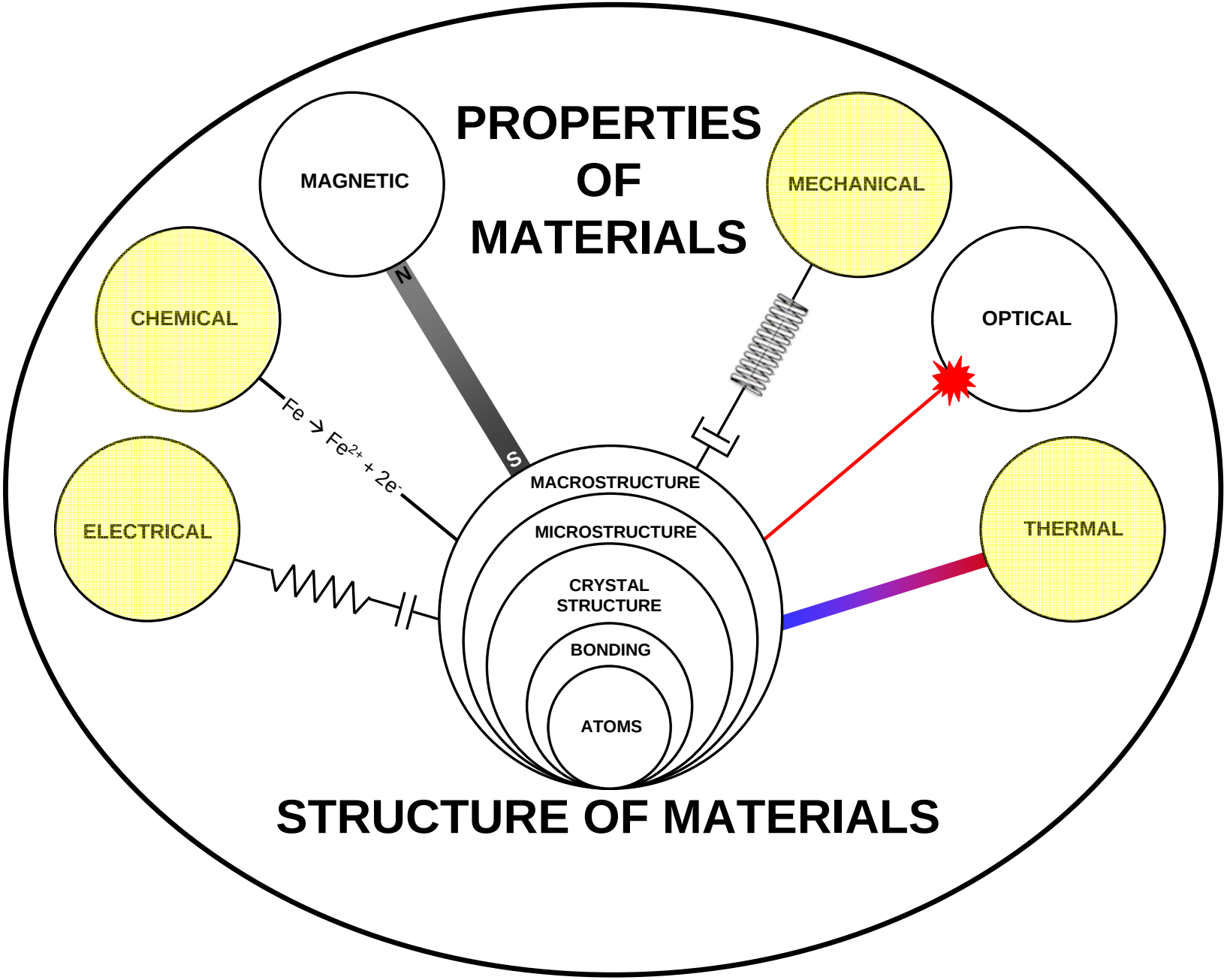


STRUCTURE OF MATERIALS

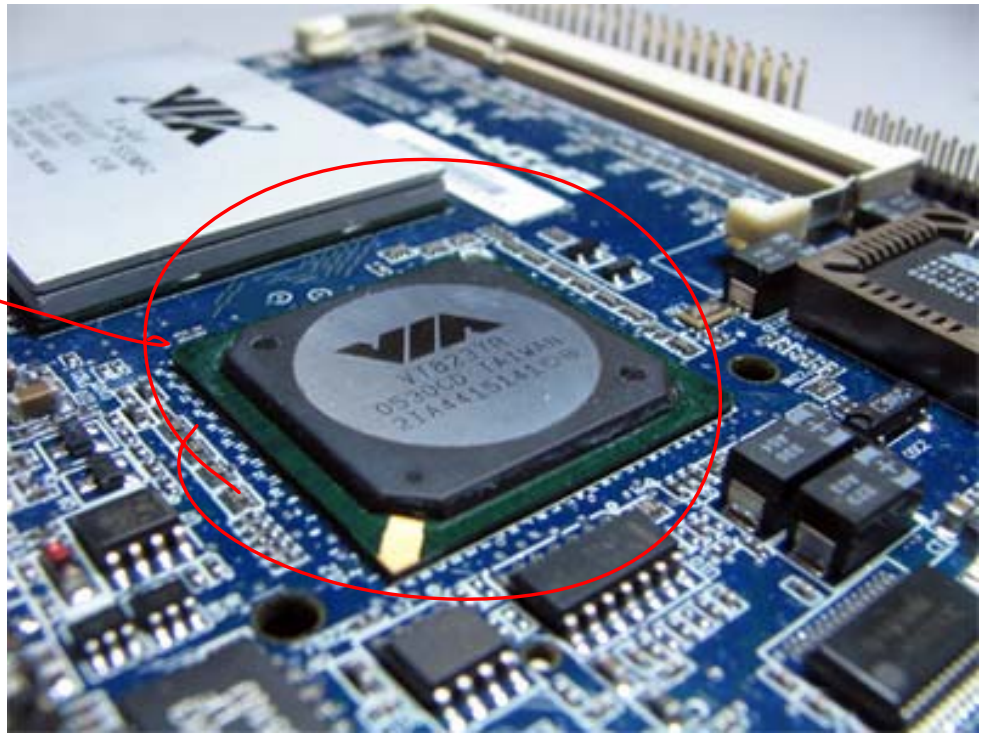


STRUCTURE OF MATERIALS

ENGINEERING APPLICATIONS



FLIP CHIP
BALL GRID ARRAY



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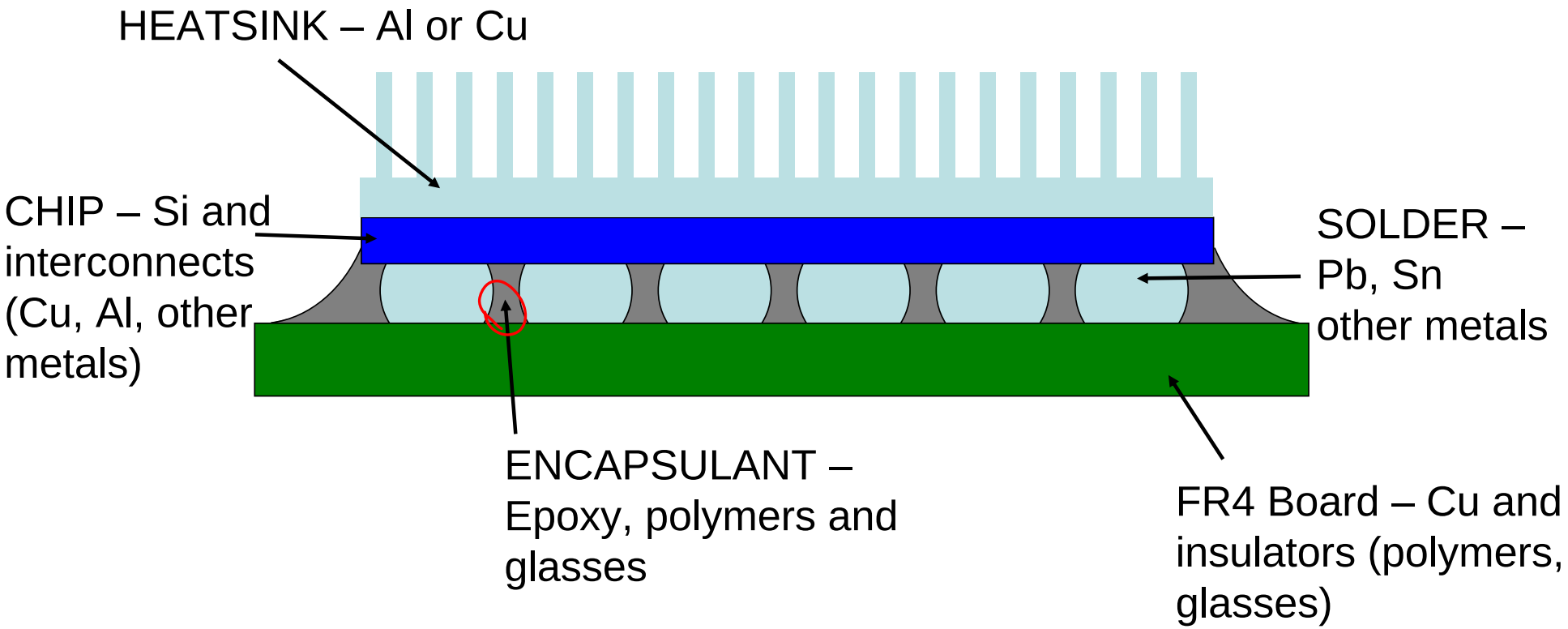

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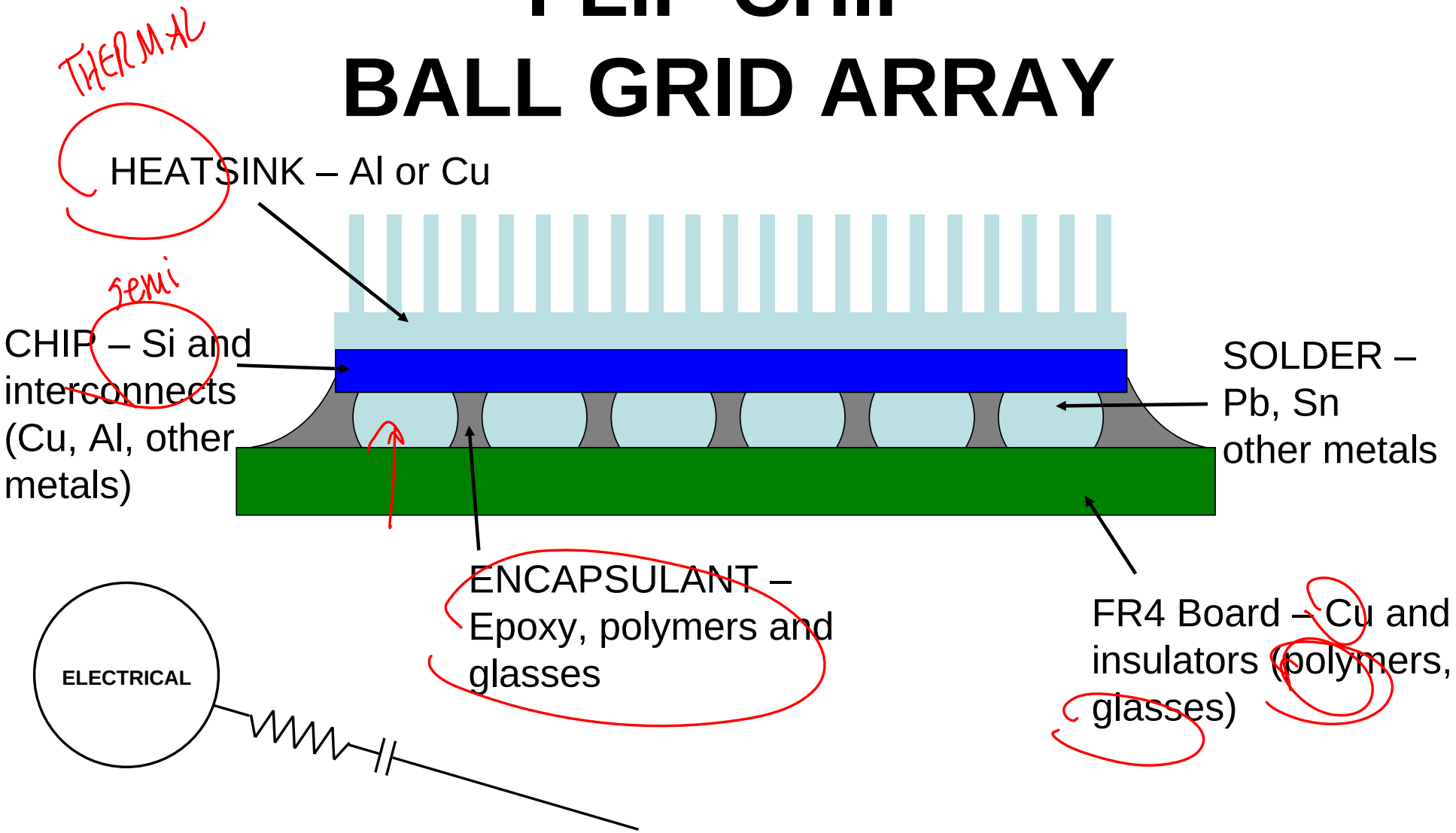

With respect to electrical properties, describe the function/role of the materials listed above.

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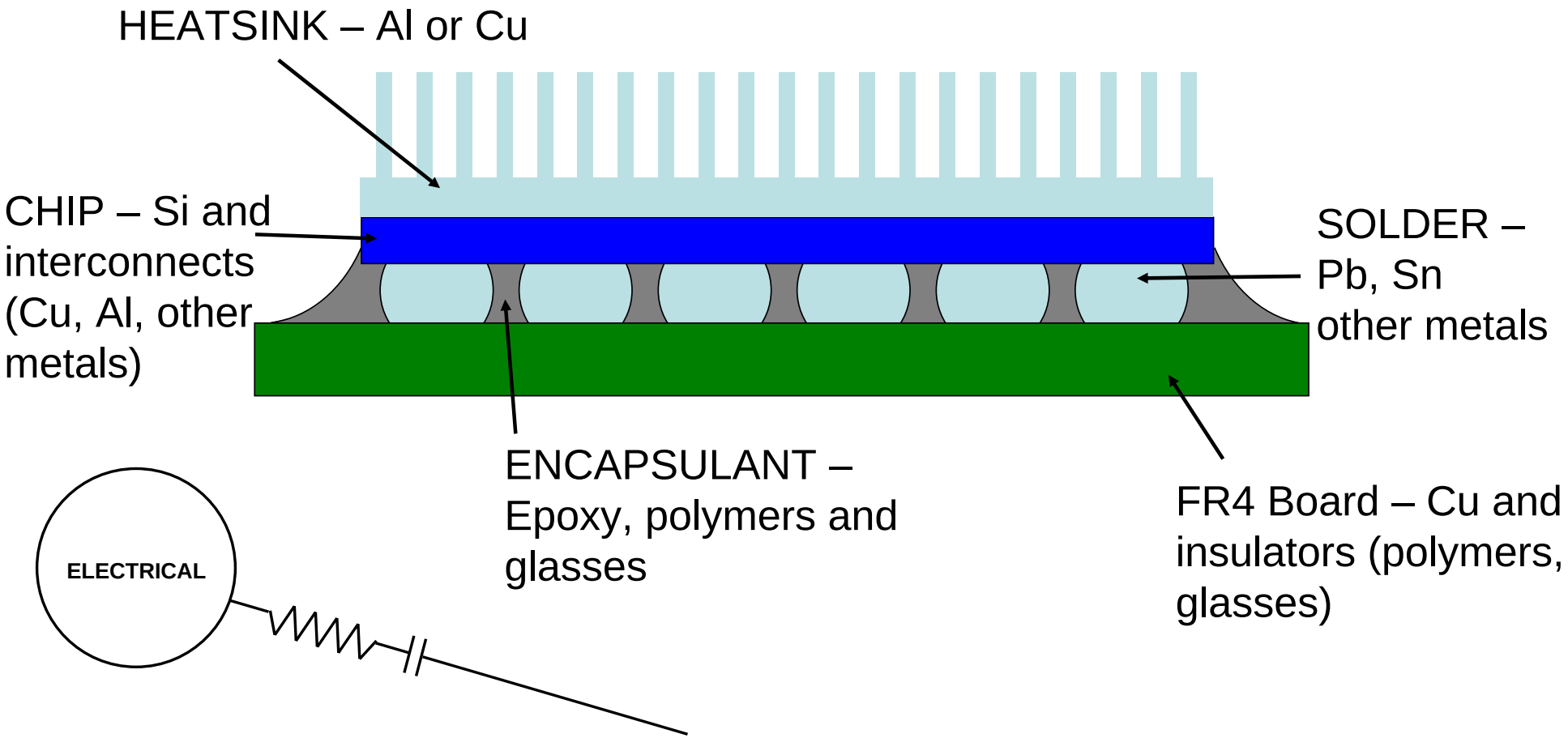

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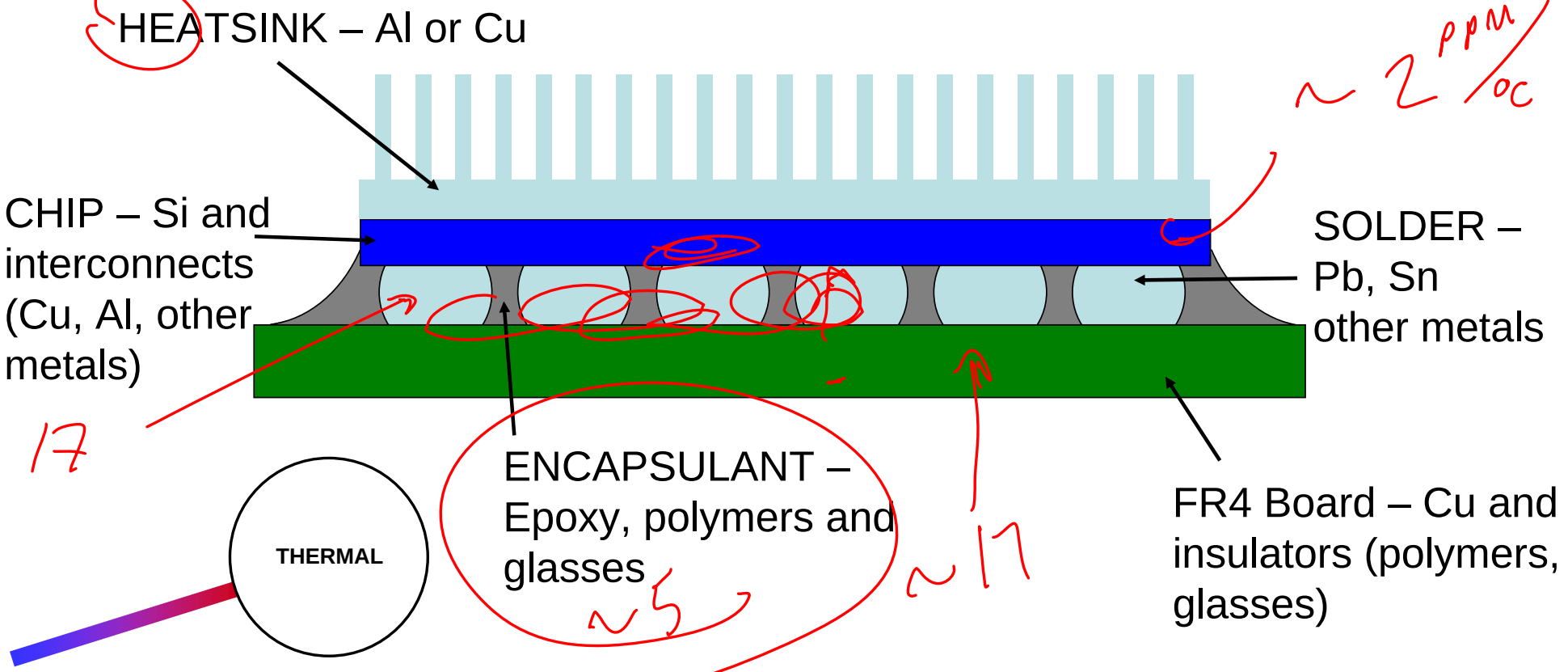

With respect to thermal properties, describe the function/role of the materials listed above.

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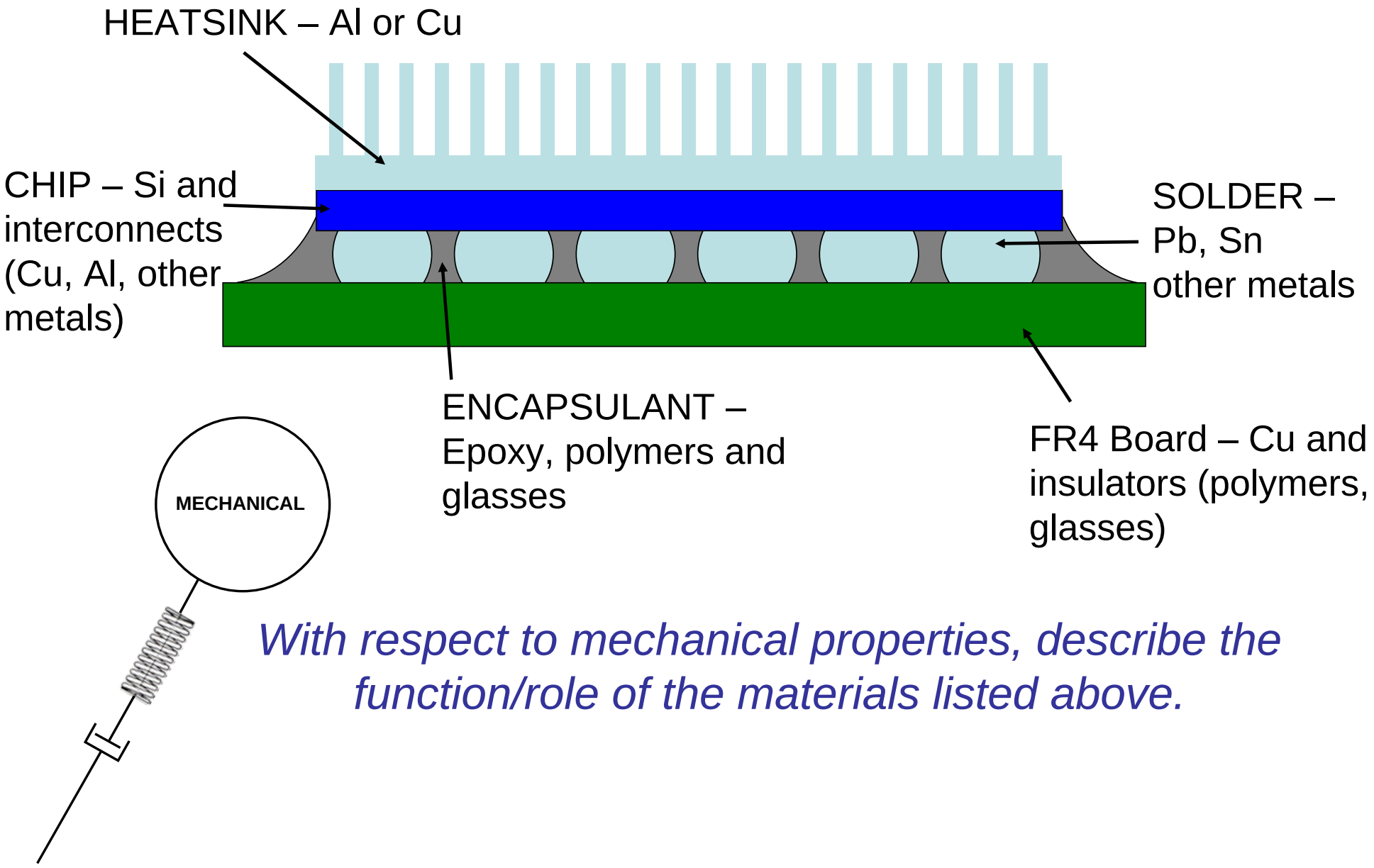
BALL GRID ARRAY



With respect to mechanical properties, describe the function/role of the materials listed above.

FLIP CHIP
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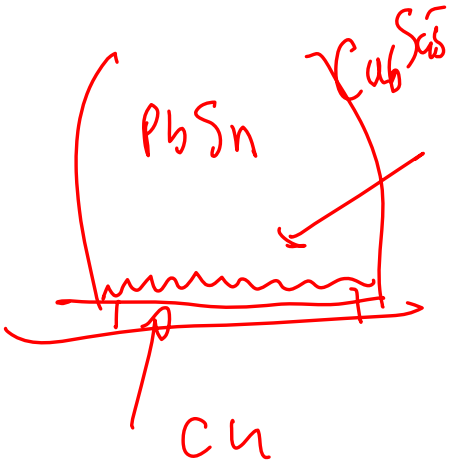
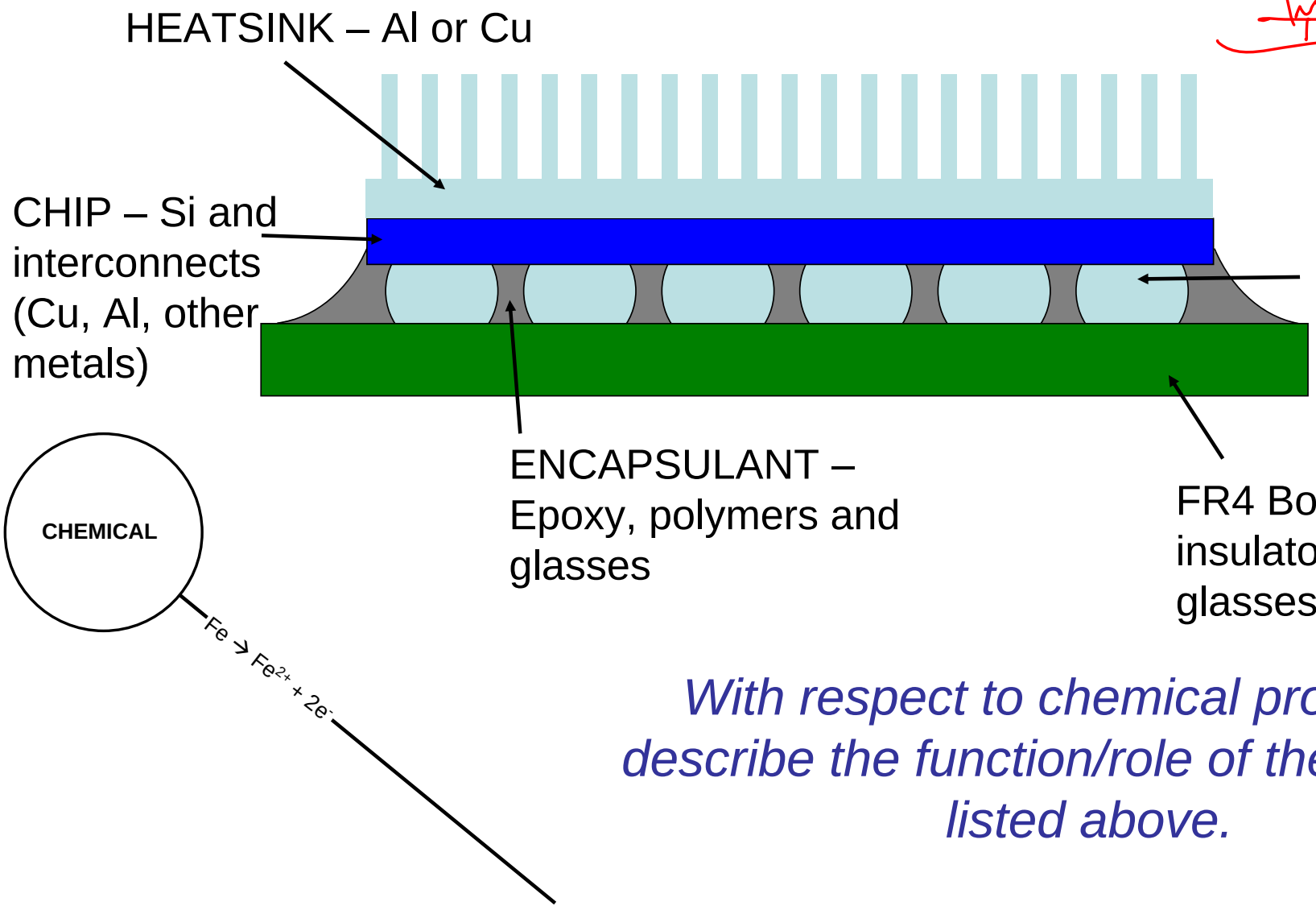




With respect to chemical properties, describe the function/role of the materials listed above.

Types of Materials

- **Metals**:
  - Strong, ductile
  - high thermal & electrical conductivity
  - opaque, reflective.

- **Polymers/plastics**: Covalent bonding → sharing of e's
  - Soft, ductile, low strength, low density
  - thermal & electrical insulators
  - Optically translucent or transparent.

- **Ceramics**: ionic bonding (refractory) – compounds of metallic & non-metallic elements (oxides, carbides, nitrides, sulfides)
  - Brittle, glassy, elastic
  - non-conducting (insulators)

The Materials Selection Process

1. Pick Application ⟶ Determine required Properties

   Properties: mechanical, electrical, thermal, magnetic, optical, chemical.

2. Properties ⟶ Identify candidate Material(s)

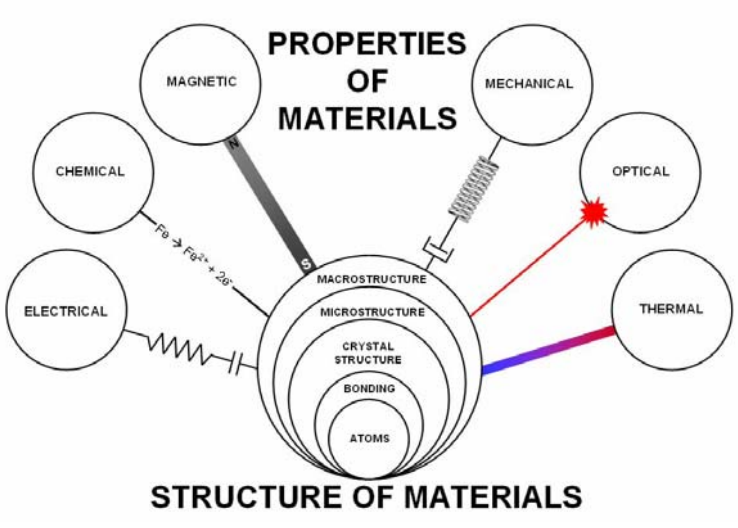
   Material: structure, composition.

3. Material ⟶ Identify required Processing

   Processing: changes *structure* and overall *shape*
   ex: casting, sintering, vapor deposition, doping
   forming, joining, annealing.

MIME262 – Properties of Materials in Electrical Engineering

- By the end of this course, students will be able to:
  - Classify materials based on their properties.
  - Explain how properties are measured.
  - Explain how structure is characterized at different length scales.
  - Recognize links between structure and properties for a variety of materials.
  - Illustrate the use of different materials in the field of electrical engineering.
  - Apply their knowledge of materials in their chosen field of electrical engineering.



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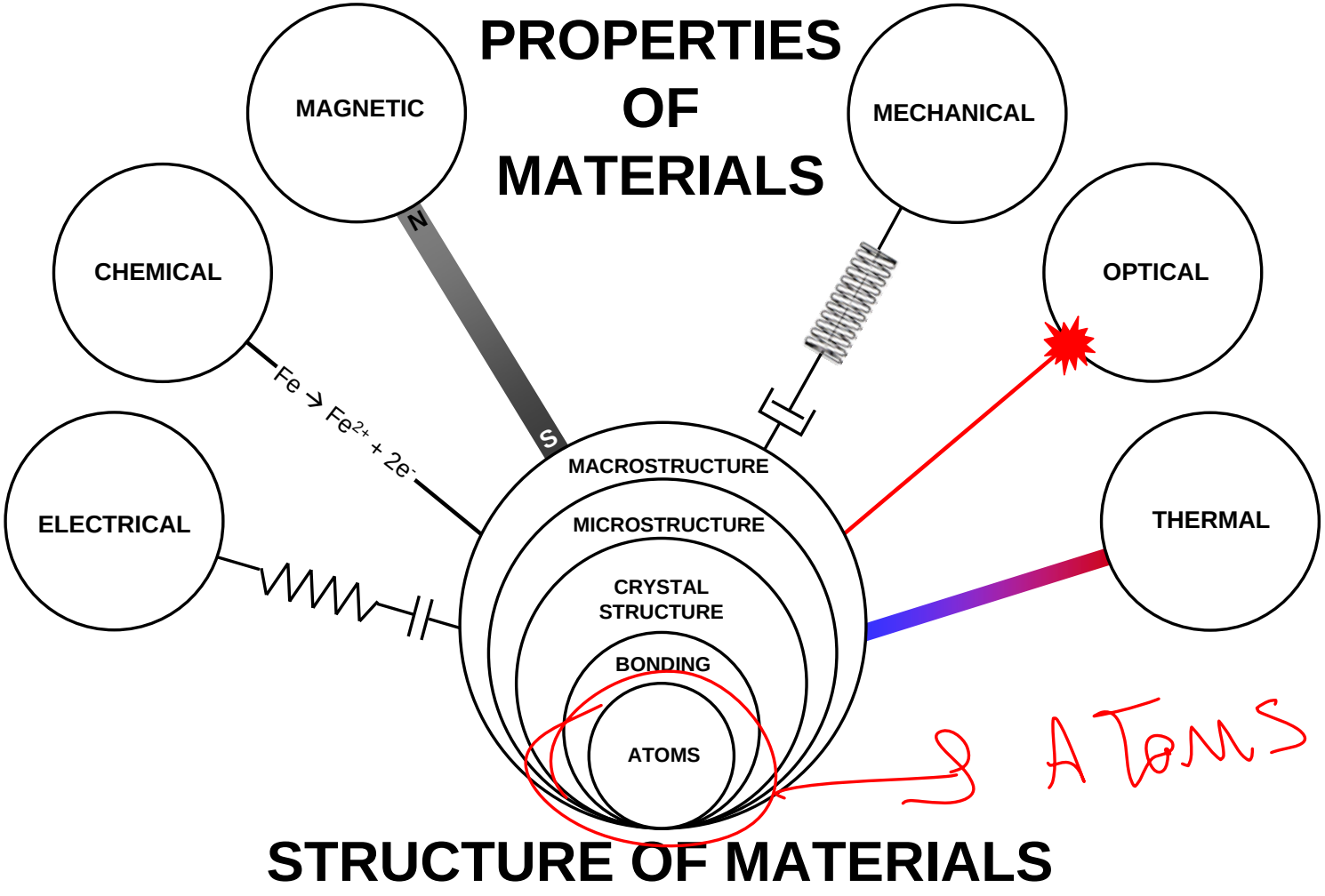


Starting point – Review of atoms, electronic structure and periodic table

Atomic Structure (Freshman Chem.)

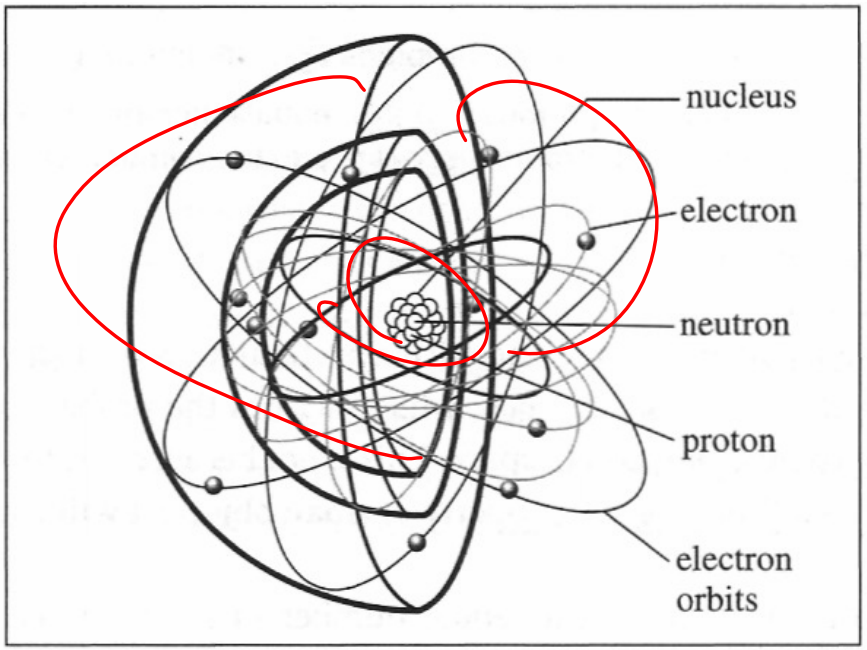
- atom – electrons – 9.11×10^{-31} kg
  protons, neutrons } 1.67×10^{-27} kg
- atomic number (Z) = # of protons in nucleus of atom
  = # of electrons of neutral species

nucleus = protons ⊙ + neutrons ○

number of protons roughly equals number of neutrons

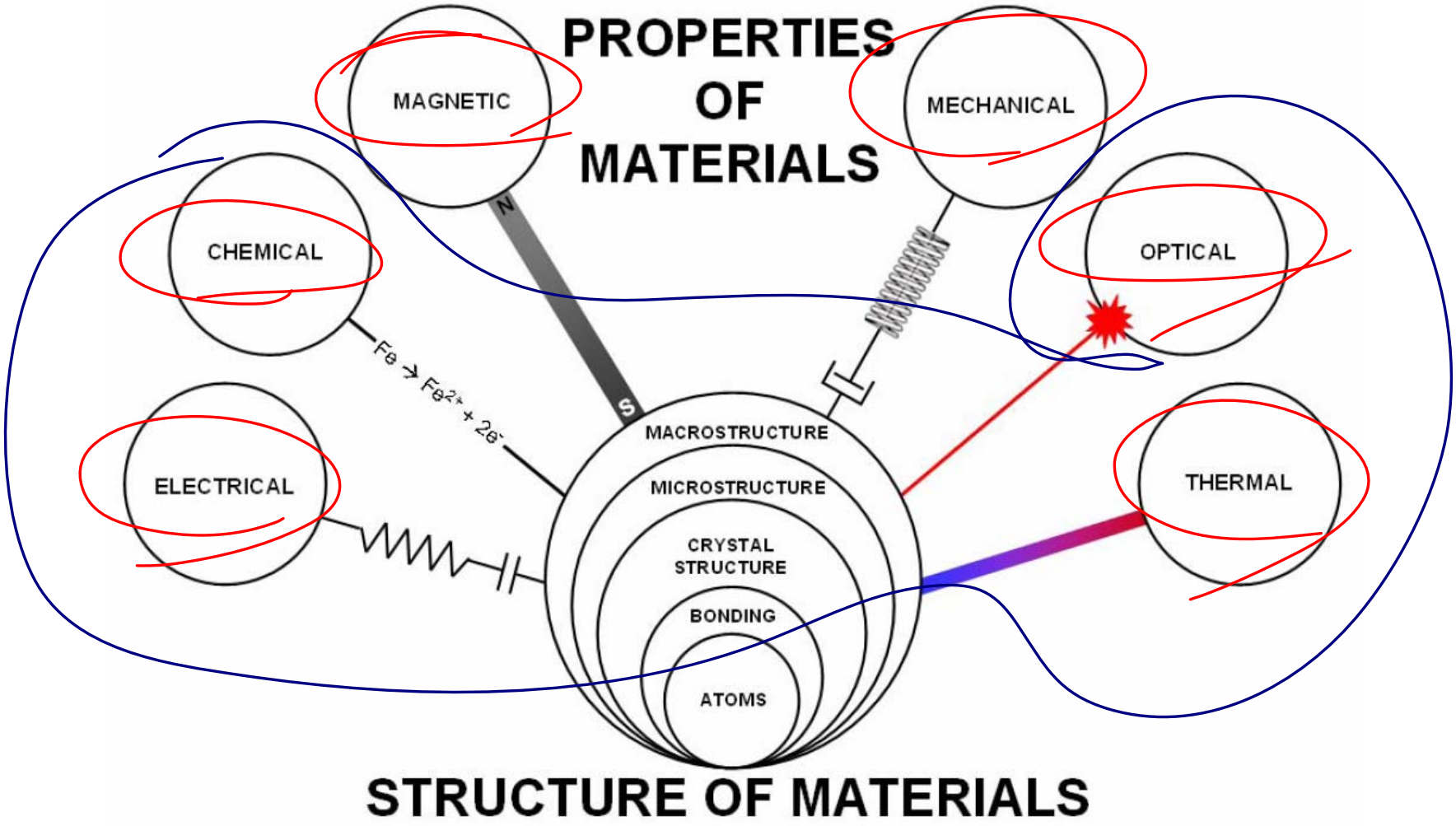
number of protons exactly equals number of electrons

ISOTOPE



Atomic Structure

- Valence electrons determine which of the four following properties?



Electronic Structure

- Electrons have wavelike and particulate properties.
  - This means that electrons are in orbitals defined by a probability.
  - Each orbital at discrete energy level determined by quantum numbers.

Quantum #	Designation
n = principal	K, L, M, N, O (1, 2, 3, etc.)
(number of the shell, defines roughly the energy of the electron)	
ℓ = orbital	s, p, d, f (0, 1, 2, 3,…, n -1)
(defines shape of orbit and angular momentum, small effect on energy)	
m_l = magnetic	1, 3, 5, 7 ($-\ell$ to $+\ell$)
(no effect on energy unless in a magnetic field)	
m_s = spin	½, -½
(spin of the electron about its center, small energy effect)	

Electronic Structure

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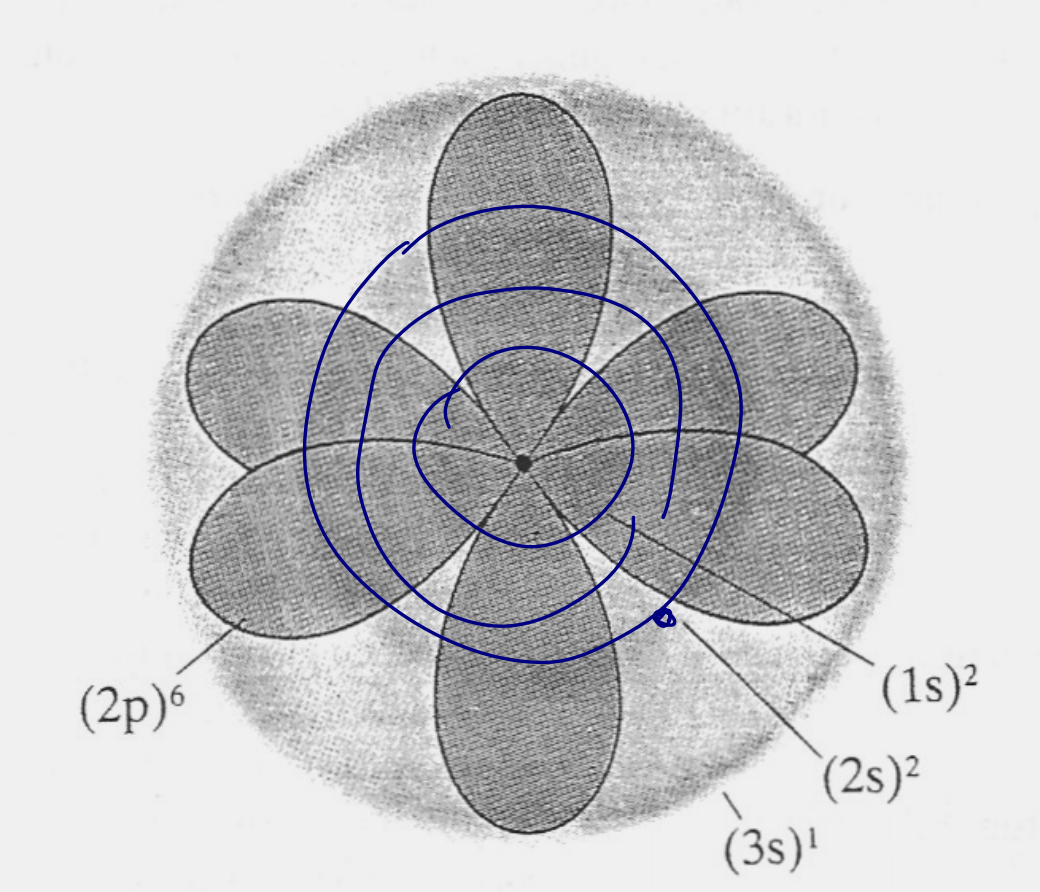


$n = 1, 2$

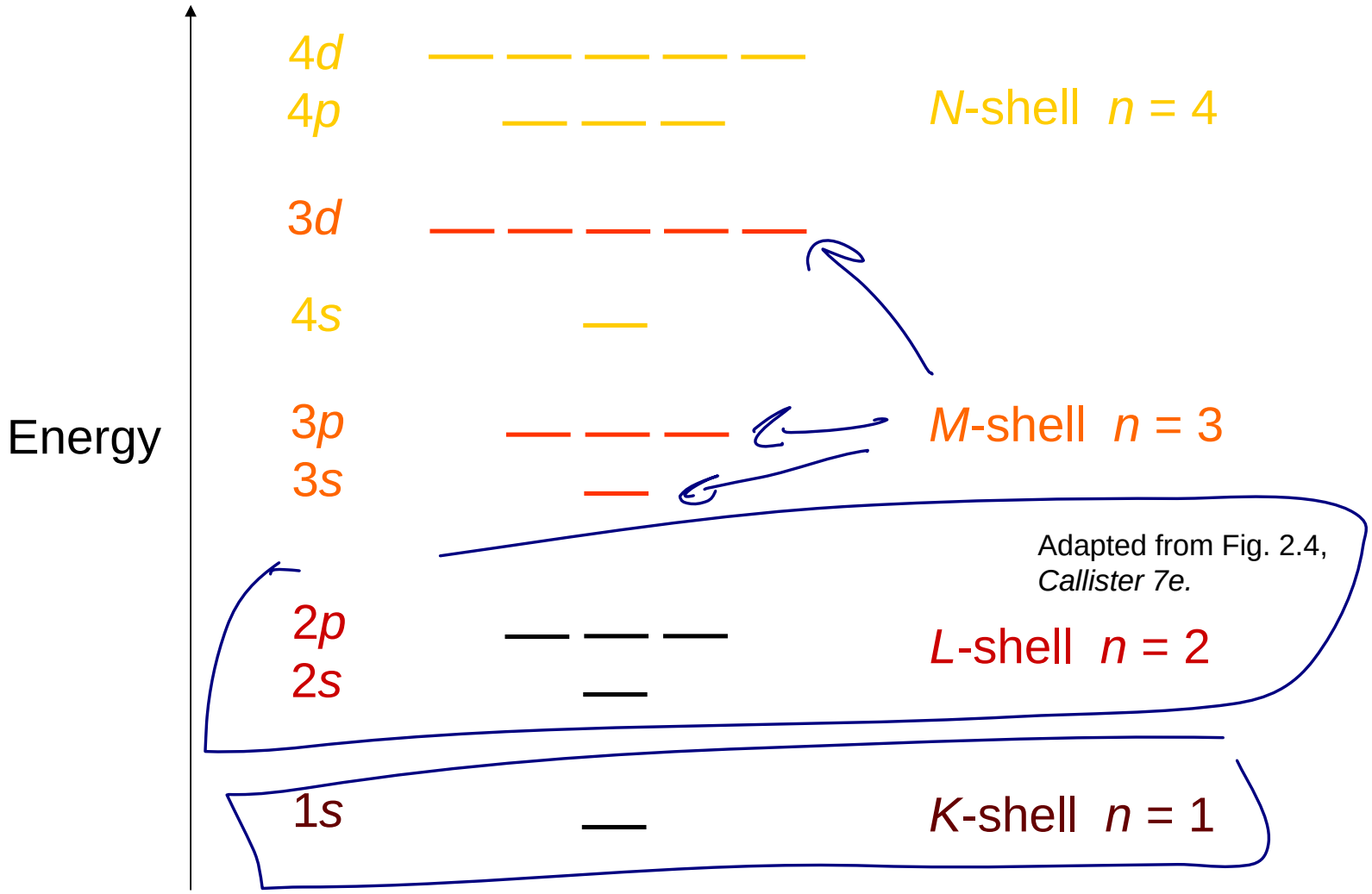
1(s) 2(p)

$l = 0$

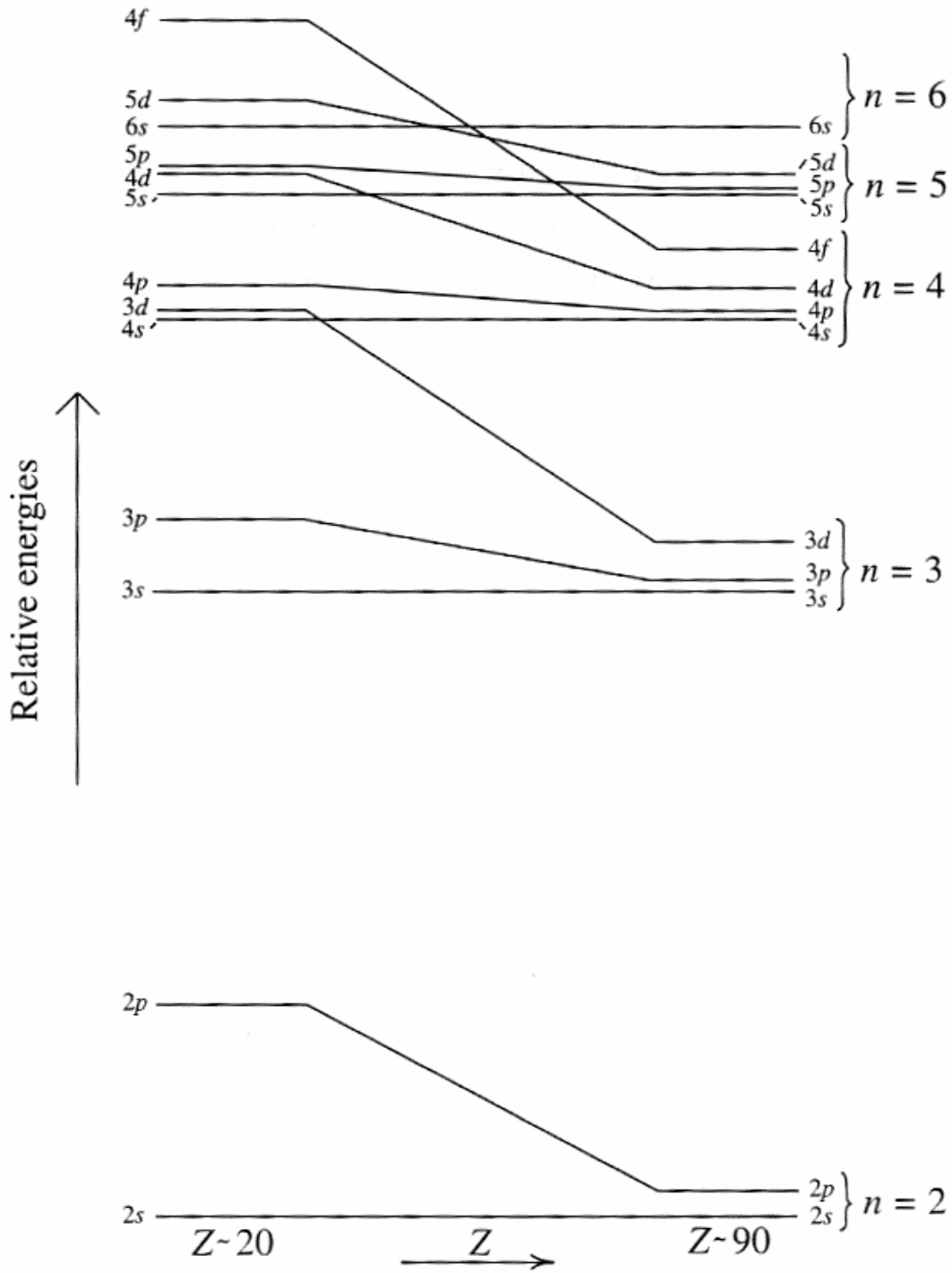
Electron Energy States

Electrons...

- have discrete energy states
- tend to occupy lowest available energy state.



Electron Energy States



SURVEY OF ELEMENTS

- Most elements: Electron configuration not stable.

Element	Atomic #	Electron configuration
Hydrogen	1	$1s^1$
Helium	2	$1s^2$ (stable)
Lithium	3	$1s^2 2s^1$
Beryllium	4	$1s^2 2s^2$
Boron	5	$1s^2 2s^2 2p^1$
Carbon	6	$1s^2 2s^2 2p^2$
...		...
Neon	10	$1s^2 2s^2 2p^6$ (stable)
Sodium	11	$1s^2 2s^2 2p^6 3s^1$
Magnesium	12	$1s^2 2s^2 2p^6 3s^2$
Aluminum	13	$1s^2 2s^2 2p^6 3s^2 3p^1$
...		...
Argon	18	$1s^2 2s^2 2p^6 3s^2 3p^6$ (stable)
...	...	...
Krypton	36	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ (stable)

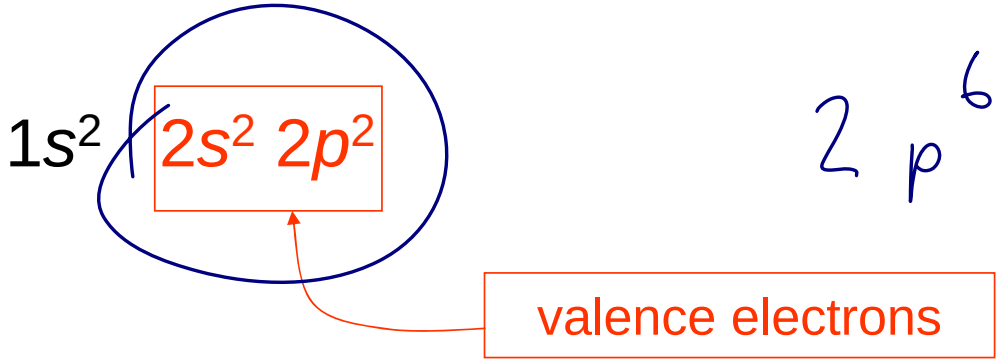
Adapted from Table 2.2, *Callister 7e.*

- Why? Valence (outer) shell usually not filled completely.

Electron Configurations

- Valence electrons – those in unfilled shells
- Filled shells more stable
- Valence electrons are most available for bonding and tend to control the chemical properties

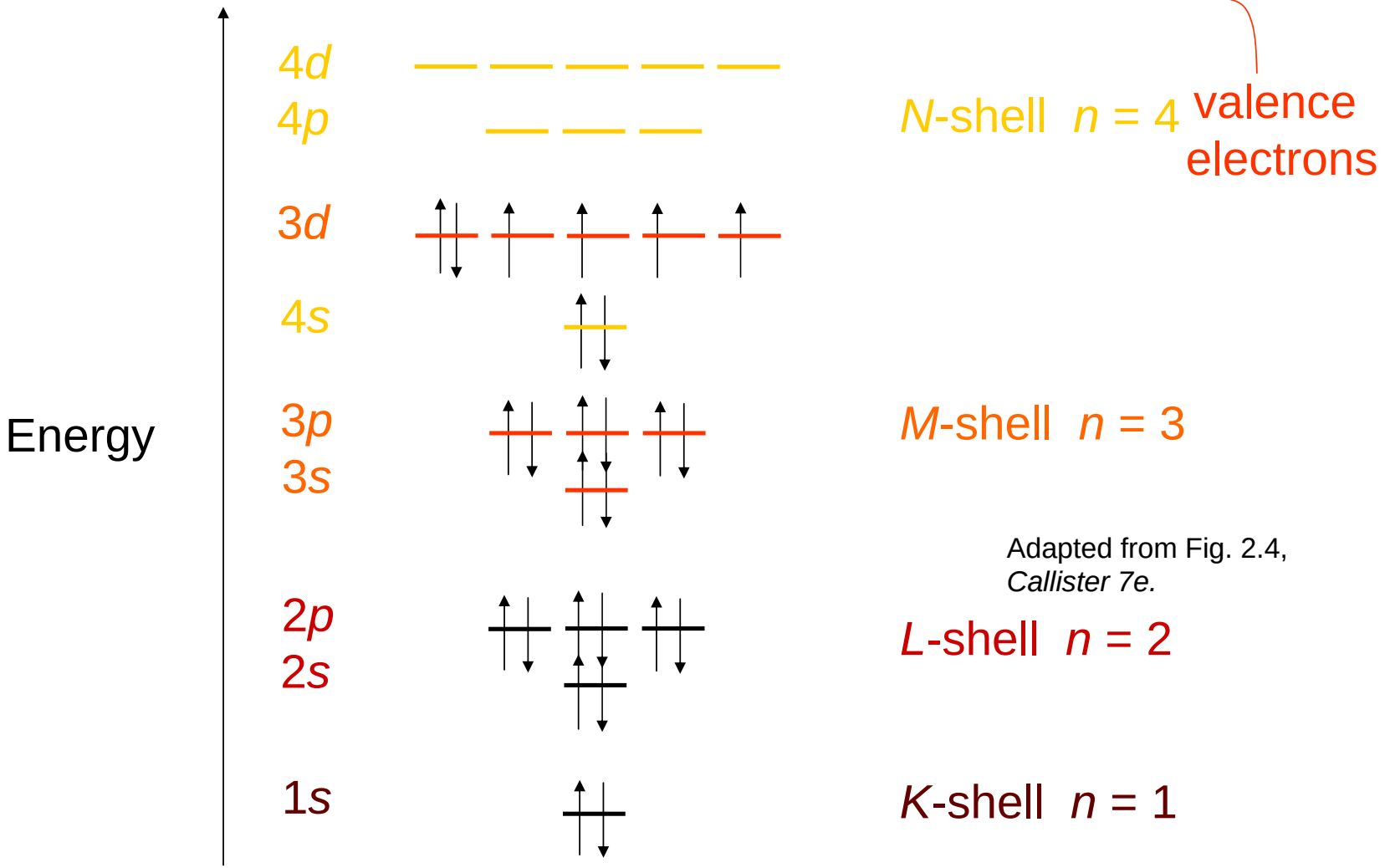
  – example: C (atomic number = 6)



$2p^6$

Electronic Configurations

ex: Fe - atomic # = 26 $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^6$ $4s^2$



Adapted from Fig. 2.4, *Callister 7e.*

Next time

- Lecture
  - Different types of bonding, why they occur and for what atoms.
  - Crystal structures
- Tutorials
  - Start tomorrow with Group B
  - Take a short survery & ungraded quiz
- Assignments
  - Read the sections of Callister defined on course schedule.
  - Start looking at solved problems for Ch. 2 on the Wiley website:

    http://www.wiley.com/college/callister