

متالورژی فیزیکی

جلسه دوم : ساختار فلزات

علی اشرفی

دانشکده مهندسی مواد

دانشگاه صنعتی اصفهان

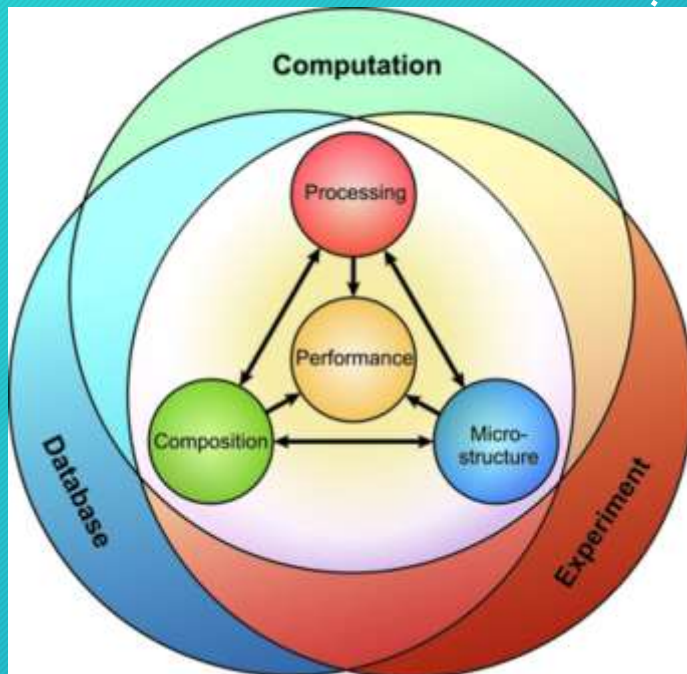


دانشگاه صنعتی اصفهان
Isfahan University
of Technology

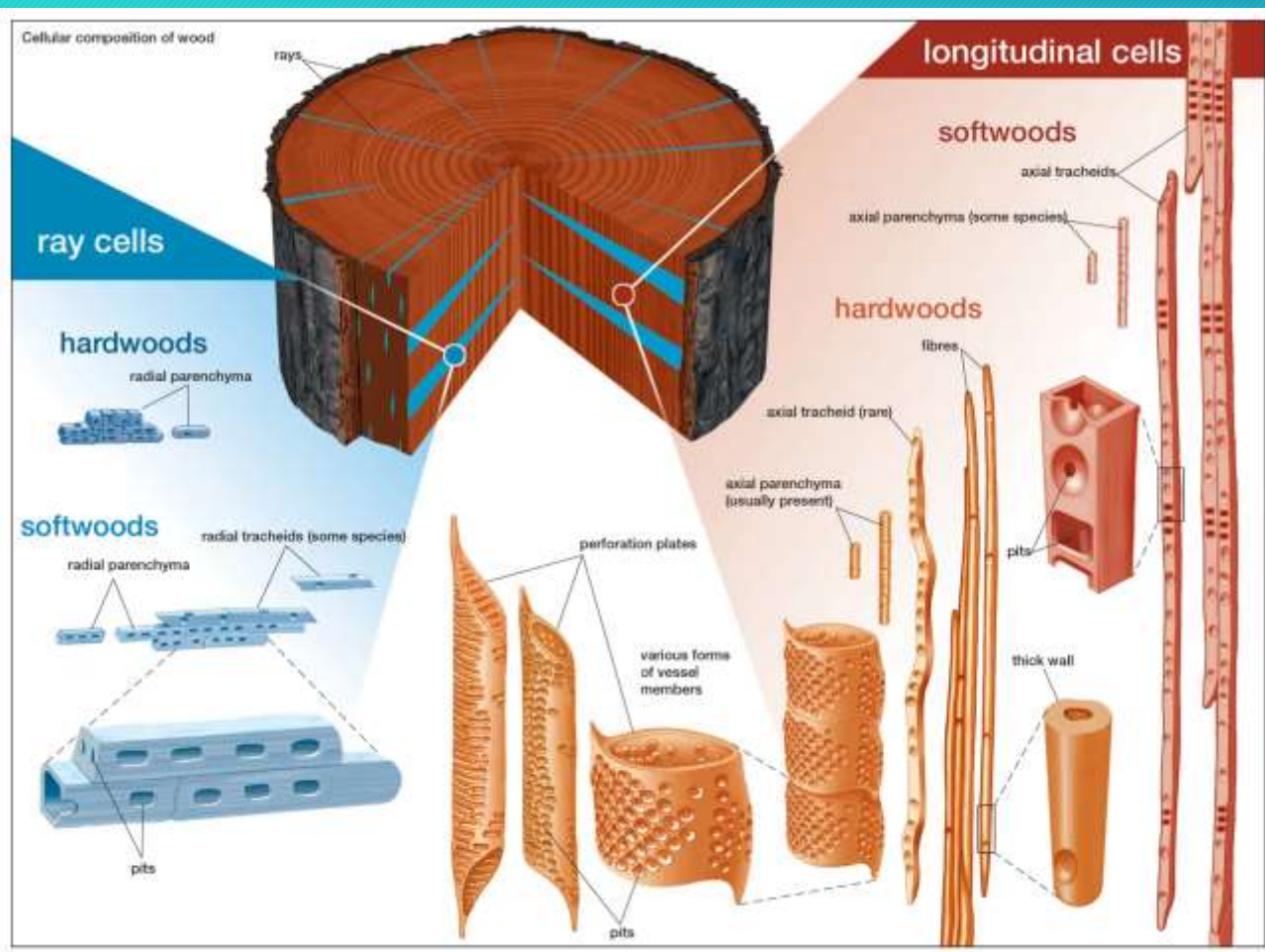
دسته بندی مواد مهندسی



- یکی از مهمترین جنبه های مواد مهندسی، ساختار آن هاست. چراکه خواص مواد ارتباط بسیار تنگاتنگی با ساختار مواد دارد.
- یک مهندس مواد باید فهم دقیقی از ارتباط بین ساختار و خواص مواد داشته باشد.



خواص و ساختار چوب



- ساختار سلول های طولی
- ابعاد ، شکل و اندازه سلول ها
- ضخامت جداره سلول ها
- تعداد خلل و فرج و ابعاد آن ها

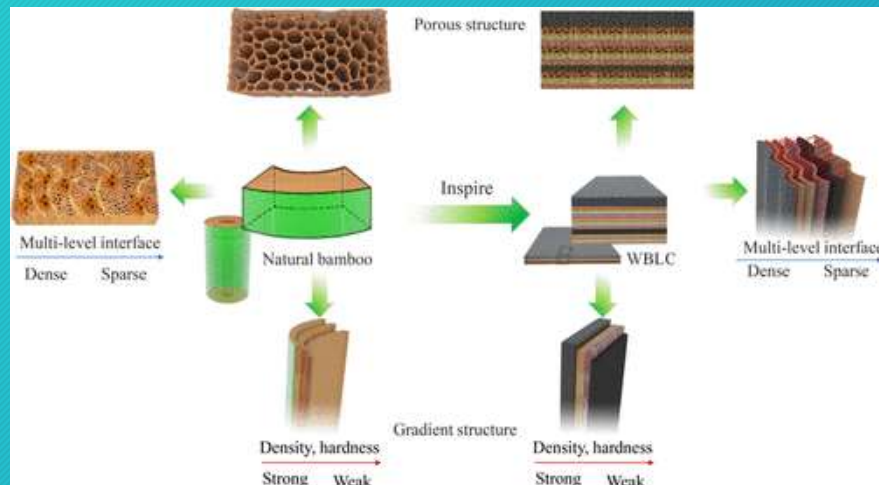
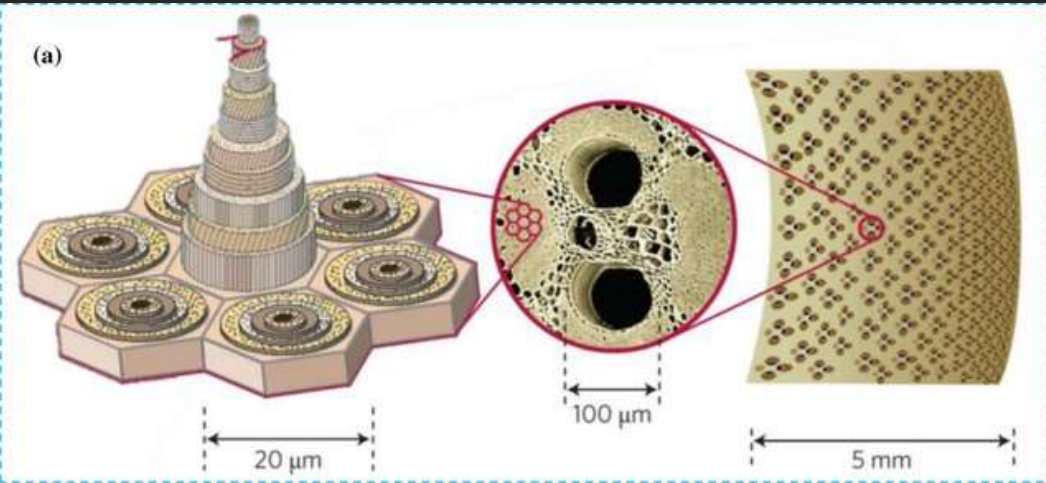
- نوع بارگذاری بر روی چوب
- (کششی، فشاری، برشی، ...)

- رفتار متفاوت چوب در جهات مختلف

ساختار بامبو



Wood Bamboo laminated Composite (WBLC)



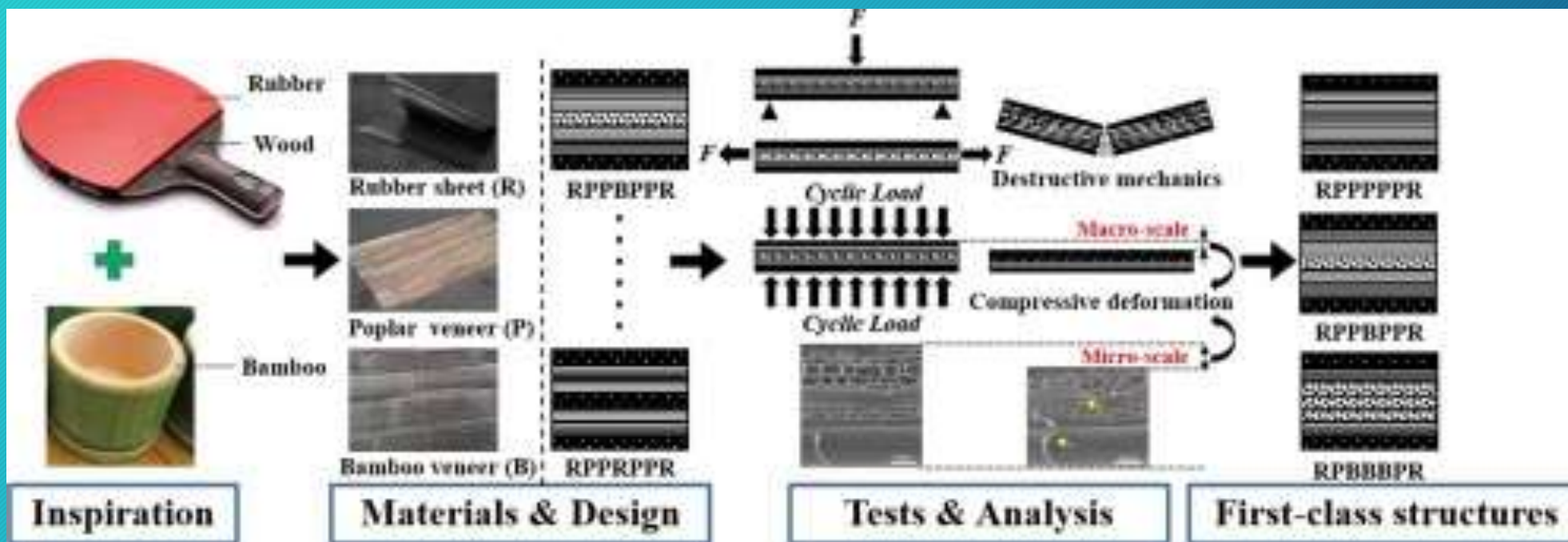
Ref: DOI: [10.1007/s10853-022-07982-3](https://doi.org/10.1007/s10853-022-07982-3)
& DOI: [10.1021/acsami.2c09785](https://doi.org/10.1021/acsami.2c09785)

<https://jungleculture.eco/blogs/news/can-bamboo-be-grown-in-the-uk>

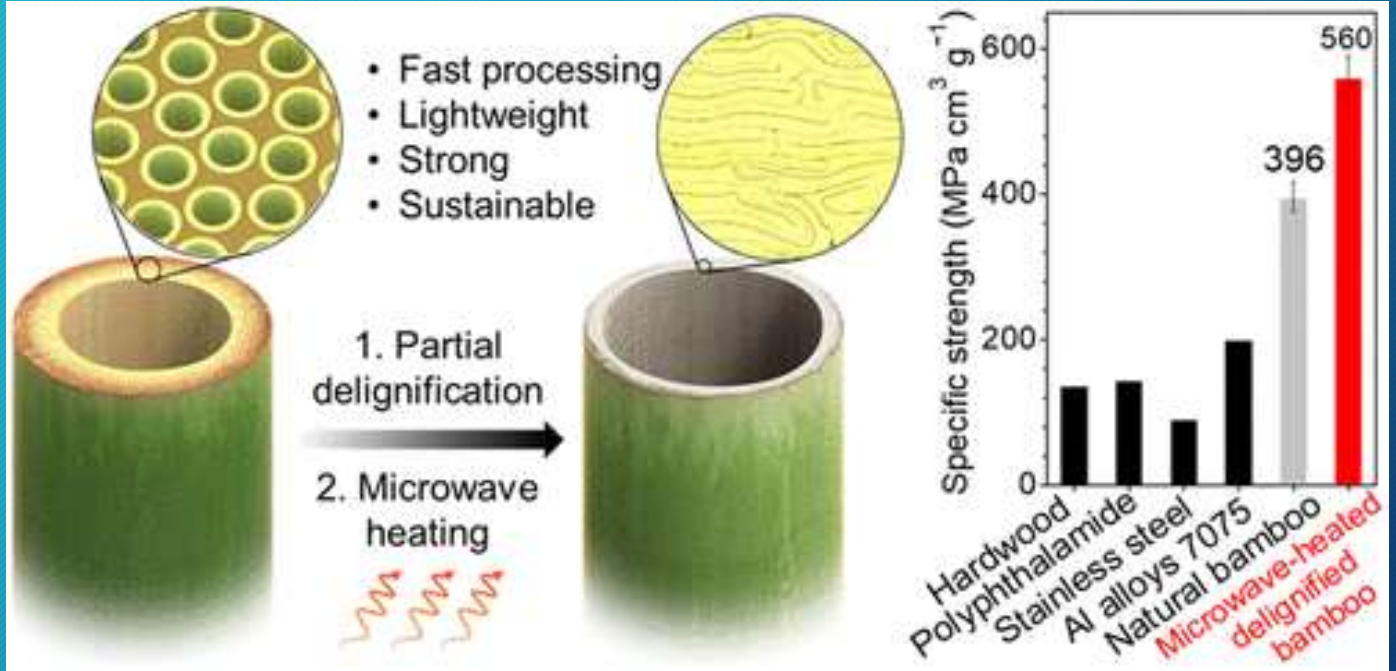
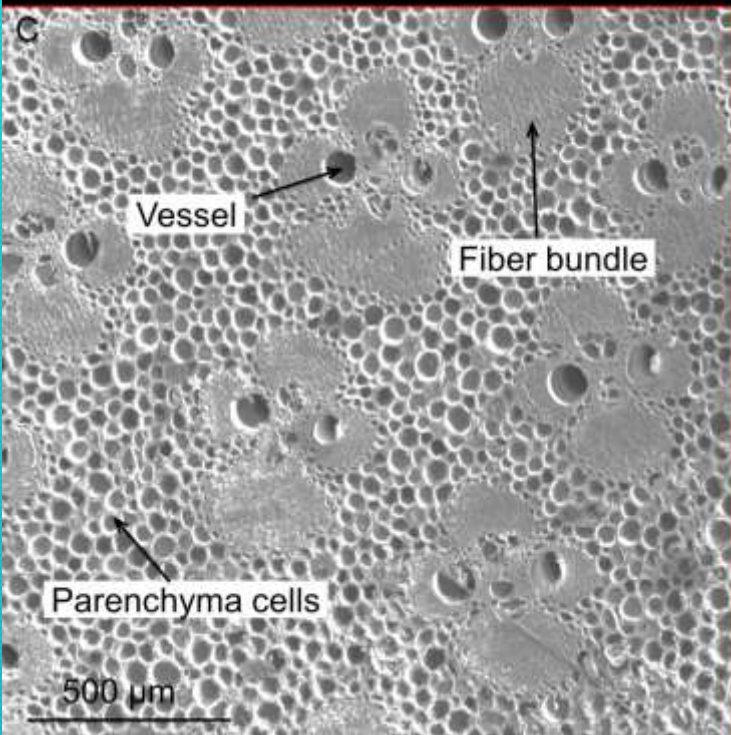
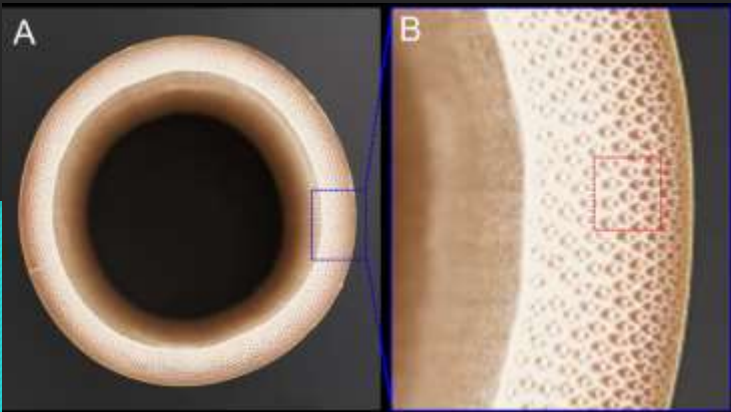
<https://omysa.com/blogs/planting-101/best-places-for-lucky-bamboo-in-your-home-and-office>

ارتباط ساختار بامبو و کاربردهای آن

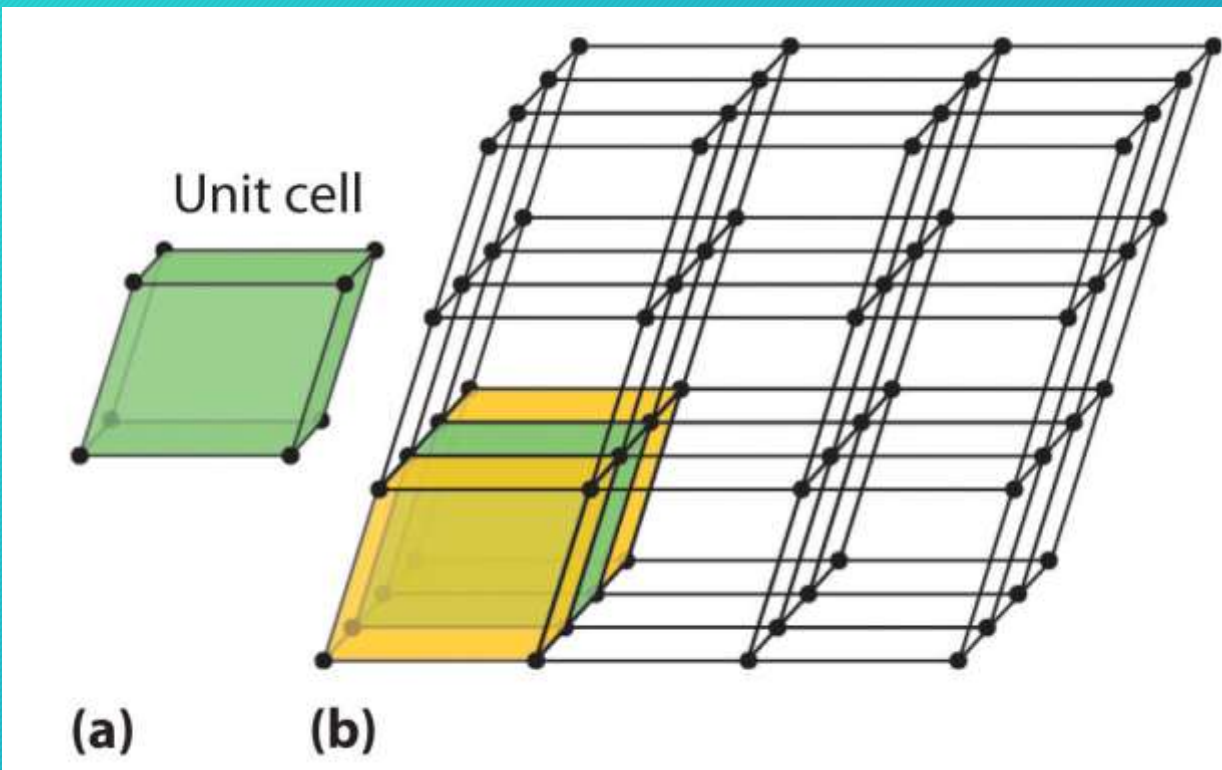
- ارتباط بین ساختار و خاصیت و کاربرد



امکان بهینه سازی خواص با تغییر در ساختار مواد

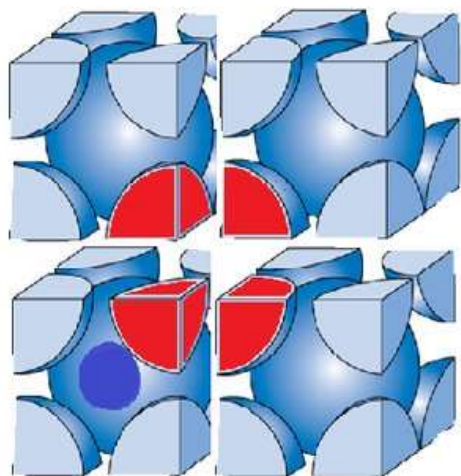
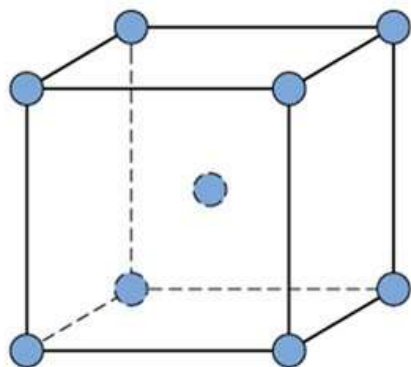
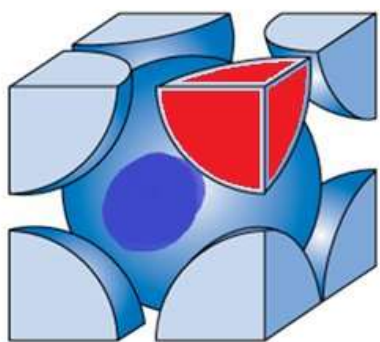


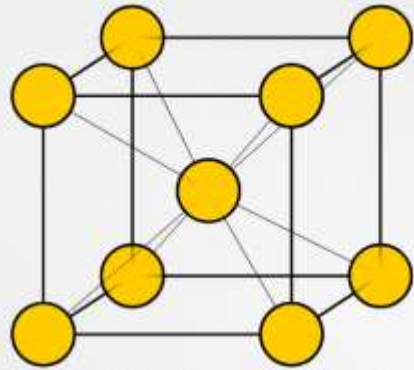
سلول واحد



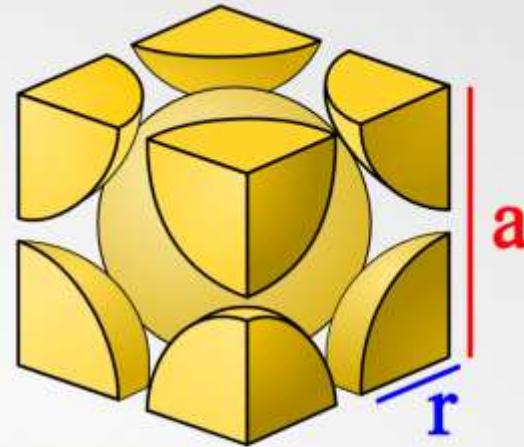
- کوچکترین گروه اتم ها
با نظم مشابه کل بلور به عنوان
واحد تکرار شونده برای ساخت بلور

ساختار مکعبی مرکز دار (BCC)





Body-Centered Cubic
Open Visualization



8 atoms on each corner,
with 1/8 of its volume
inside the unit cell

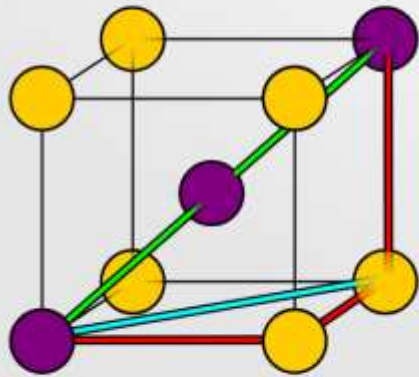
+1 full atom inside

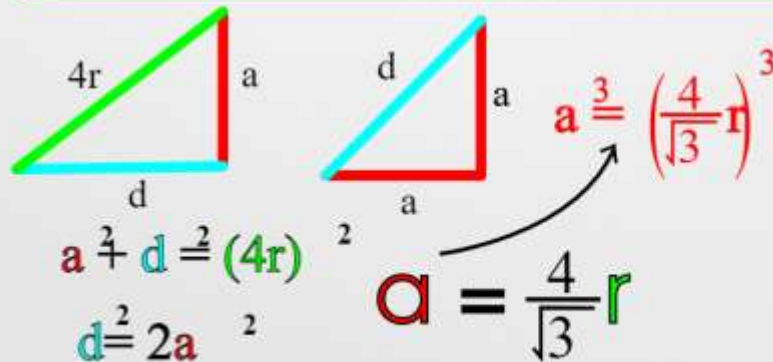
= 2 atoms per unit cell

$$\text{APF} = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}}$$

Volume of atoms = $2 \cdot \frac{4}{3} \pi r^3$

Volume of cube = $\left(\frac{4}{\sqrt{3}} r\right)^3$





$$a^2 + d^2 = (4r)^2$$

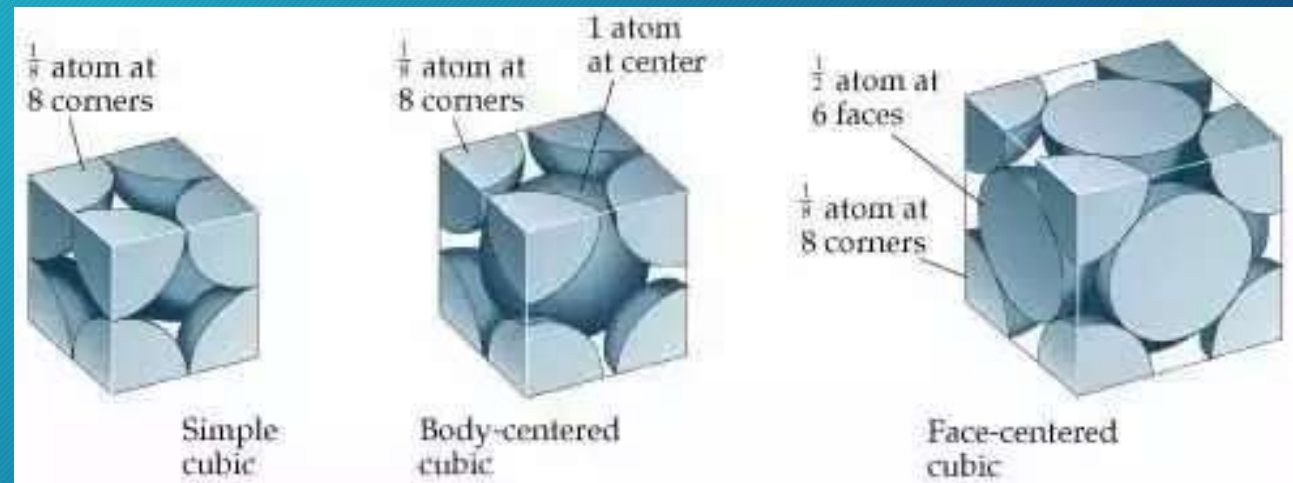
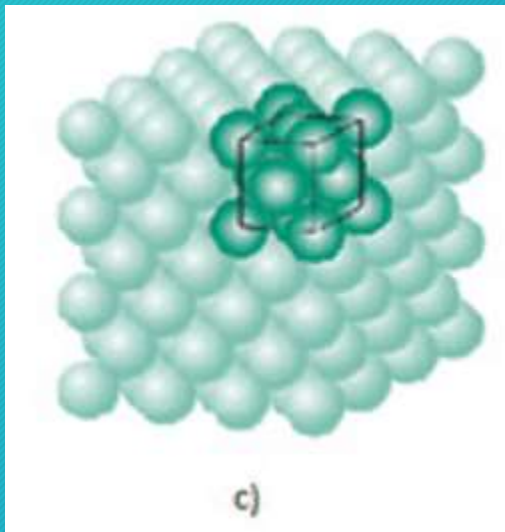
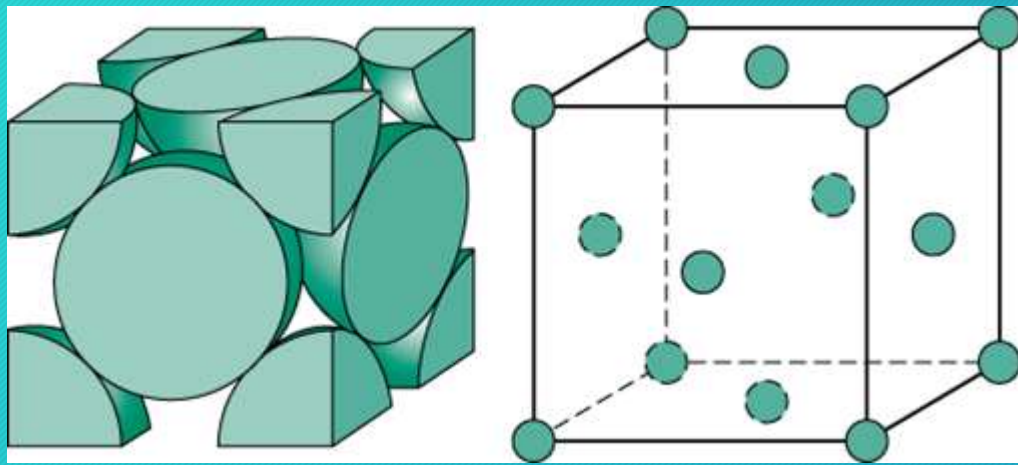
$$d^2 = 2a^2$$

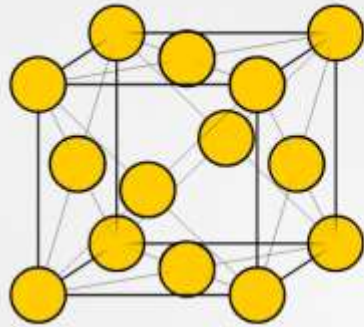
$$a = \frac{4}{\sqrt{3}} r$$

For BCC

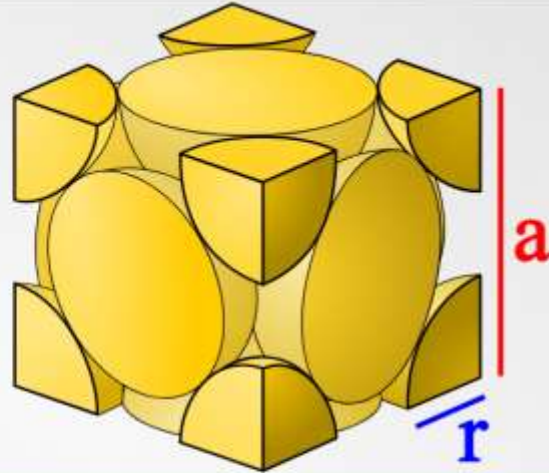
$$\text{APF} = \frac{\sqrt{3} \pi}{8} = 68\%$$

ساختار مکعبی وجه مرکز دار (FCC)





Face-Centered Cubic
Open Visualization



8 atoms on each corner,
with $1/8$ of its volume
inside the unit cell (1)

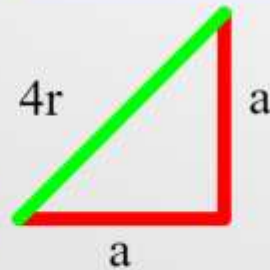
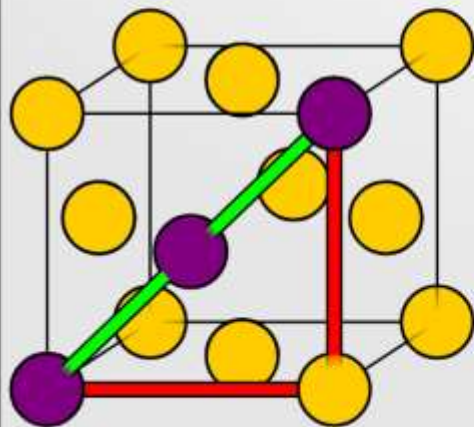
+ 6 atoms on each face
with $1/2$ of its volume
inside the unit cell (3)

= 4 atoms per unit cell

$$\text{APF} = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}}$$

Volume of atoms = $4 \cdot \frac{4}{3} \pi r^3$

Volume of cube = $(2\sqrt{2}r)^3$



$$a^3 = 16\sqrt{2}r^3$$

$$2a^2 = (4r)^2$$

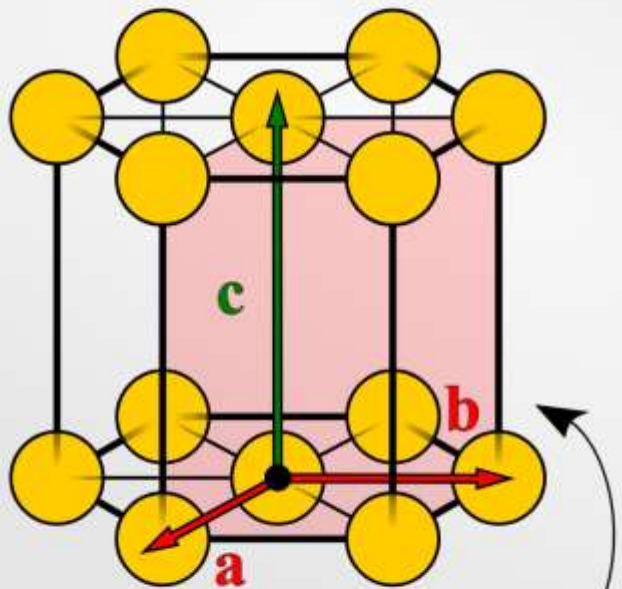
$$a = 2\sqrt{2}r$$

For FCC

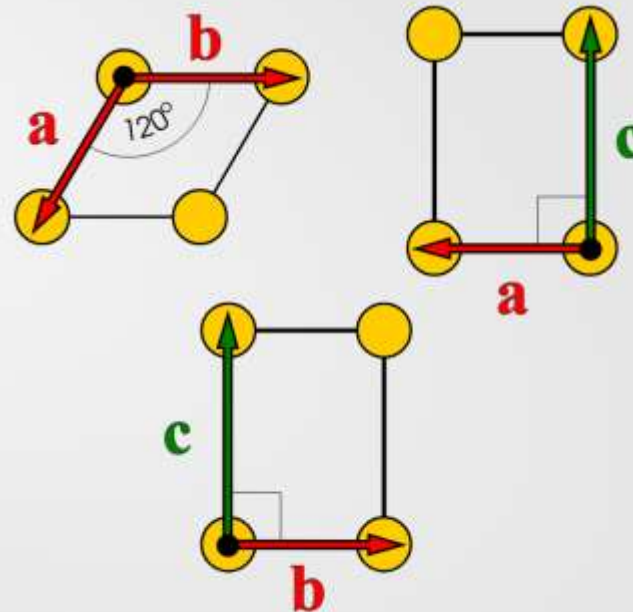
$$\text{APF} = \frac{\pi}{3\sqrt{2}} = 74\%$$

ساختار هگزاگونال ساده (Simple Hexagonal)

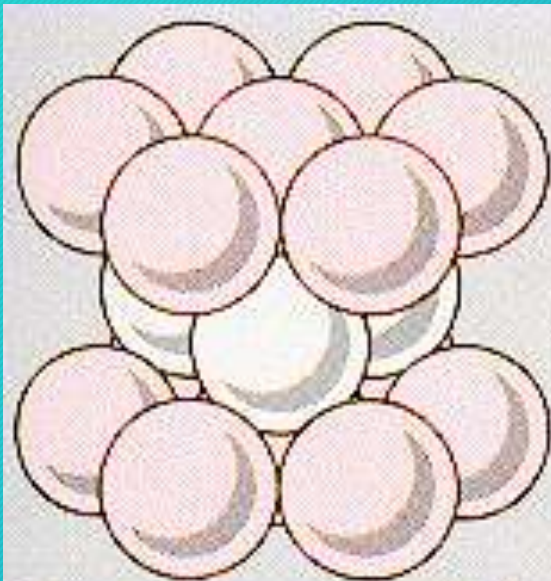
Simple Hexagonal Crystal Structure



$$a = b \neq c$$



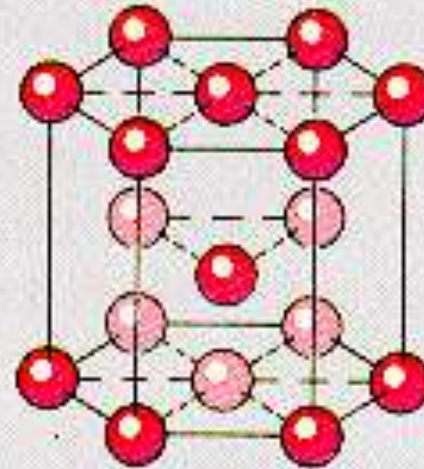
ساختار همگراگونال فشرده (HCP)



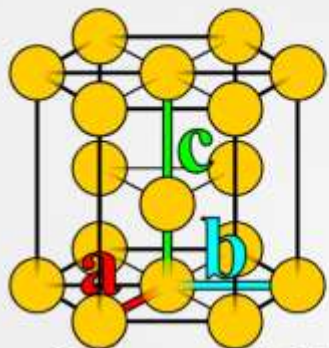
(c) hexagonal close packing



unit cell



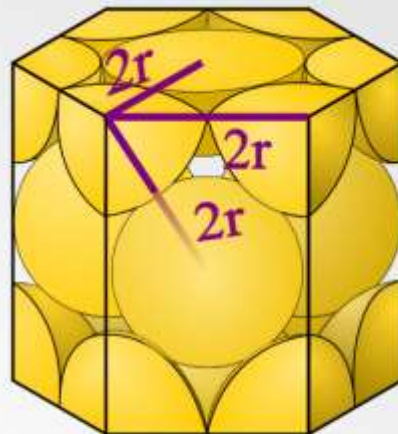
atom centres



$$a = b = 2r$$

$$c = 4\sqrt{\frac{2}{3}}r$$

Hexagonal Close-Packed
Open Visualization



12 atoms on the corners,
with 1/6 of their volume
inside the unit cell (2)

+ 3 atoms inside the cell,
with 100% of their volume
inside the unit cell (3)

+ 2 atoms on the faces,
with 1/2 of their volume
inside the unit cell (1)

= 6 atoms per unit cell

$$\text{APF} = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}}$$

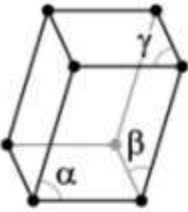
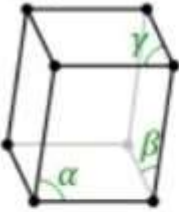
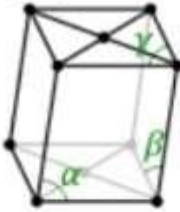
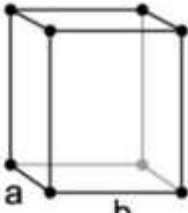
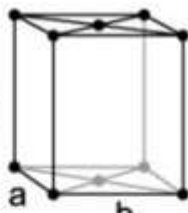
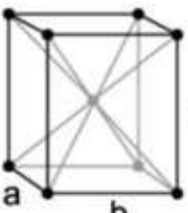
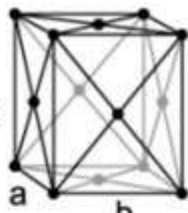
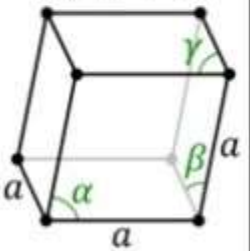
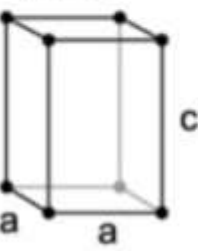
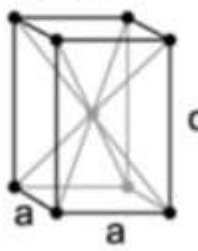
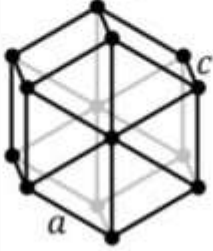
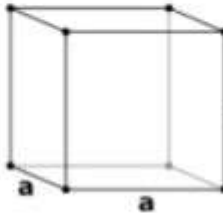
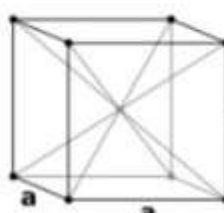

$$\text{Volume of atoms} = 6 \cdot \frac{4}{3}\pi r^3$$

$$\text{Volume of unit cell} = 24\sqrt{2}r^3$$

For HCP

$$\text{APF} = \frac{\pi}{3\sqrt{2}} = 74\%$$

شبکه های براوه (*Bravis Lattices*)

$\alpha, \beta, \gamma \neq 90^\circ$ 	$\alpha \neq 90^\circ$ $\beta, \gamma = 90^\circ$  Centered	$\alpha \neq 90^\circ$ $\beta, \gamma = 90^\circ$  Simple	$a \neq b \neq c$  Simple	$a \neq b \neq c$  Base Centered	$a \neq b \neq c$  Face Centered	$a \neq b \neq c$  Body Centered
Triclinic	Monoclinic		Orthorhombic			
$\alpha, \beta, \gamma \neq 90^\circ$ 	$a \neq c$  Simple	$a \neq c$  Body Centered	$a \neq c$ 	 Simple	 Body Centered	 Face Centered
Rhombohedral	Tetragonal		Hexagonal	Cubic (or isometric)		



Crystal Structures of Elements at STP

STP - Standard Temperature and Pressure

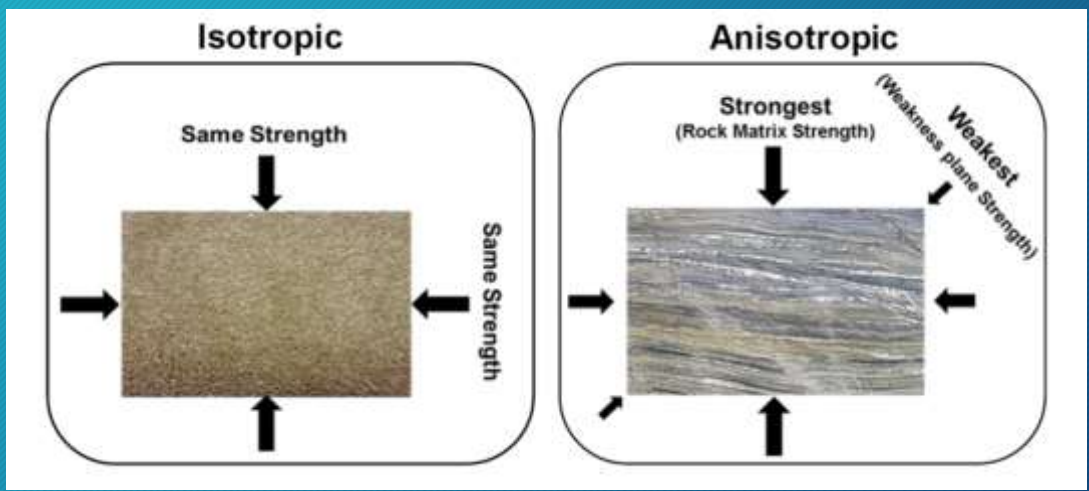
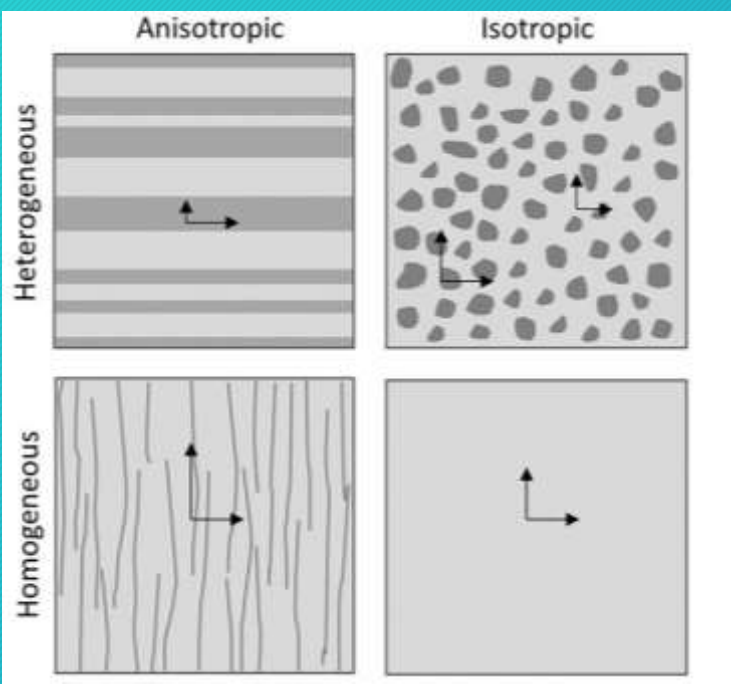
H HEX																He HCP	
Li BCC	Be HCP	BCC - Body-centered Cubic FCC - Face-centered Cubic HEX - Simple Hexagonal HCP - Close-packed Hexagonal DHCP - Double Close-packed Hexagonal RHO - Rhombohedral										B RHO	C HEX	N complex HCP	O P-cubic	F P-cubic	Ne FCC
Na BCC	Mg HCP	BCT - Body-centered Tetragonal ORTH - Orthorhombic DC - Diamond Cubic DT - Diamond Tetragonal SC - Simple Cubic * predicted crystal structure										Al FCC	Si DC	P ORTH	S ORTH	Cl complex C-ORTH	Ar FCC
K BCC	Ca FCC	Sc HCP	Ti HCP	V BCC	Cr BCC	Mn α-Mn	Fe BCC	Co HCP	Ni FCC	Cu FCC	Zn HCP	Ga complex F-ORTH	Ge DC	As P-RHO	Se complex HEX	Br complex C-ORTH	Kr FCC
Rb BCC	Sr FCC	Y HCP	Zr HCP	Nb BCC	Mo BCC	Tc HCP	Ru HCP	Rh FCC	Pd FCC	Ag FCC	Cd HCP	In BCT	Sn DT	Sb P-RHO	Te complex HEX	I complex C-ORTH	Xe FCC
Cs BCC	Ba BCC	57-71	Hf HCP	Ta BCC	W BCC	Re HCP	Os HCP	Ir FCC	Pt FCC	Au FCC	Hg RHO	Tl HCP	Pb FCC	Bi RHO	Po SC	At FCC*	Rn FCC*
Fr BCC*	Ra BCC	89-103	Rf HCP*	Db BCC*	Sg BCC*	Bh HCP*	Hs HCP*	Mt FCC*	Ds BCC*	Rg BCC*	Cn HCP*	Nh HCP*	Fl FCC*	Mc UNKNOWN	Lv UNKNOWN	Ts UNKNOWN	Og FCC*

	Solid state at STP
	Liquid state at STP
	Gaseous state at STP

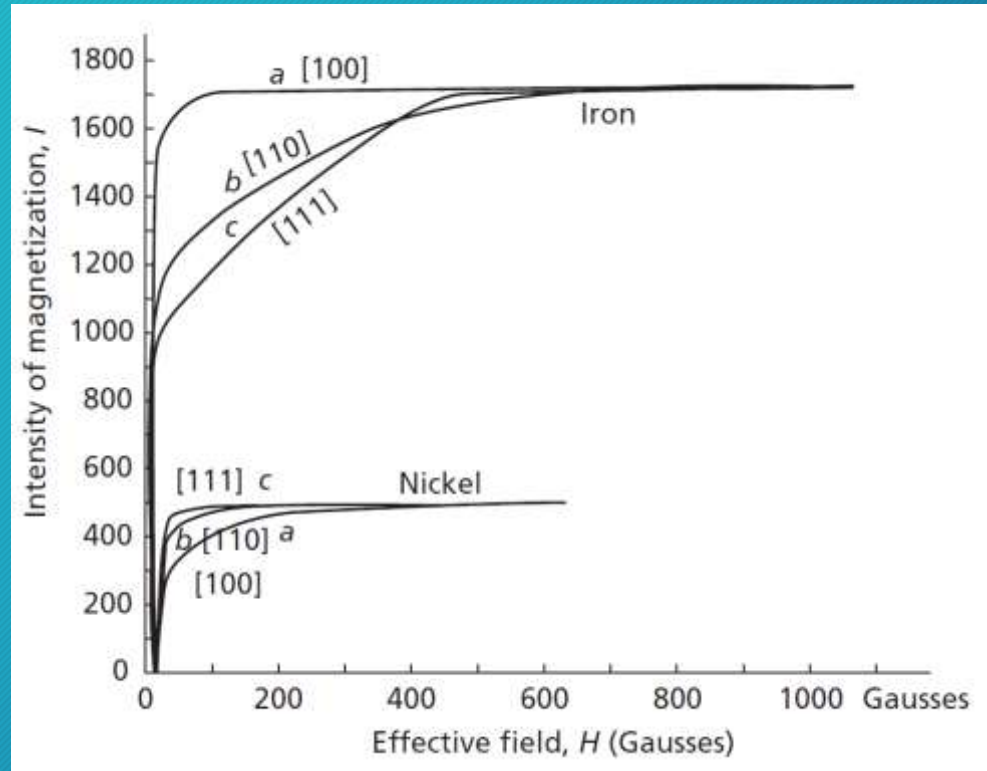
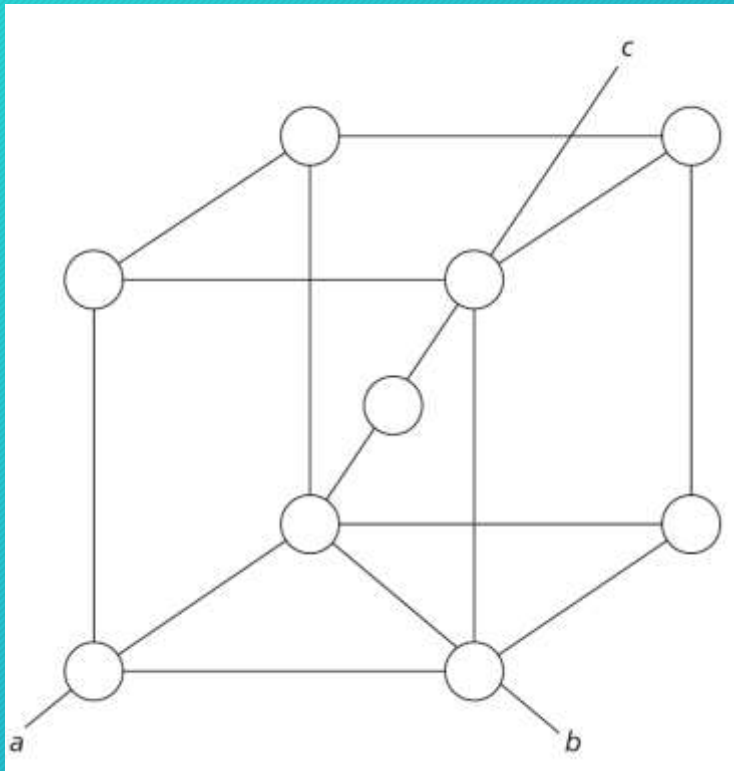
La DHCP	Ce DHCP	Pr DHCP	Nd DHCP	Pm DHCP	Sm complex RHO	Eu BCC	Gd HCP	Tb HCP	Dy HCP	Ho HCP	Er HCP	Tm HCP	Yb FCC	Lu HCP
Ac FCC	Th FCC	Pa BCT	U ORTH	Np ORTH	Pu MONO	Am DHCP	Cm DHCP	Bk DHCP	Cf DHCP	Es FCC	Fm FCC*	Md FCC*	No FCC*	Lr HCP*

همسانگردی (Isotropic) و ناهمسانگردی (Anisotropy)

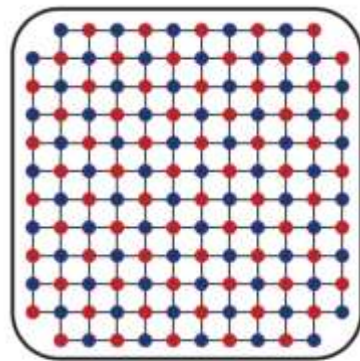
- هنگامی که خواص یک ماده به جهت وابسته نباشد، آن ماده همسانگرد نامیده می شود. خواص مزبور می تواند استحکام، مقاومت الکتریکی و ... باشد.



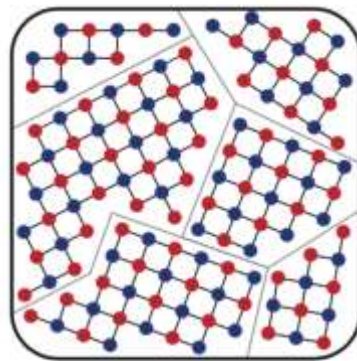
ناهمسانگردی در جهات مختلف اتمی



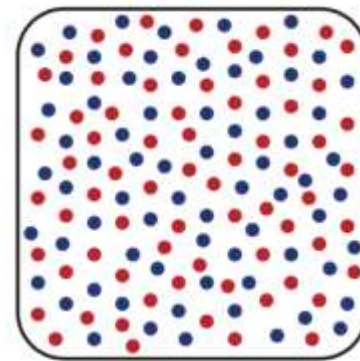
فلزات و آلیاژها، همسانگرد یا ناهمسانگرد؟



Crystalline



Polycrystalline



Amorphous

بافت (Texture) یا جهات ترجیحی (Preferred Orientation)

