



ARCHIVE EDITION

Polymers and Composites

Applications to society and the workplace, through science and technology

Suprit Pal Singh

Talk at BINUS Education Foundation, Jakarta, November 2017

POLYMERS & COMPOSITES

Awesome Applications to Society and Work Place Satisfaction by Science and Technology

Suprit Pal Singh

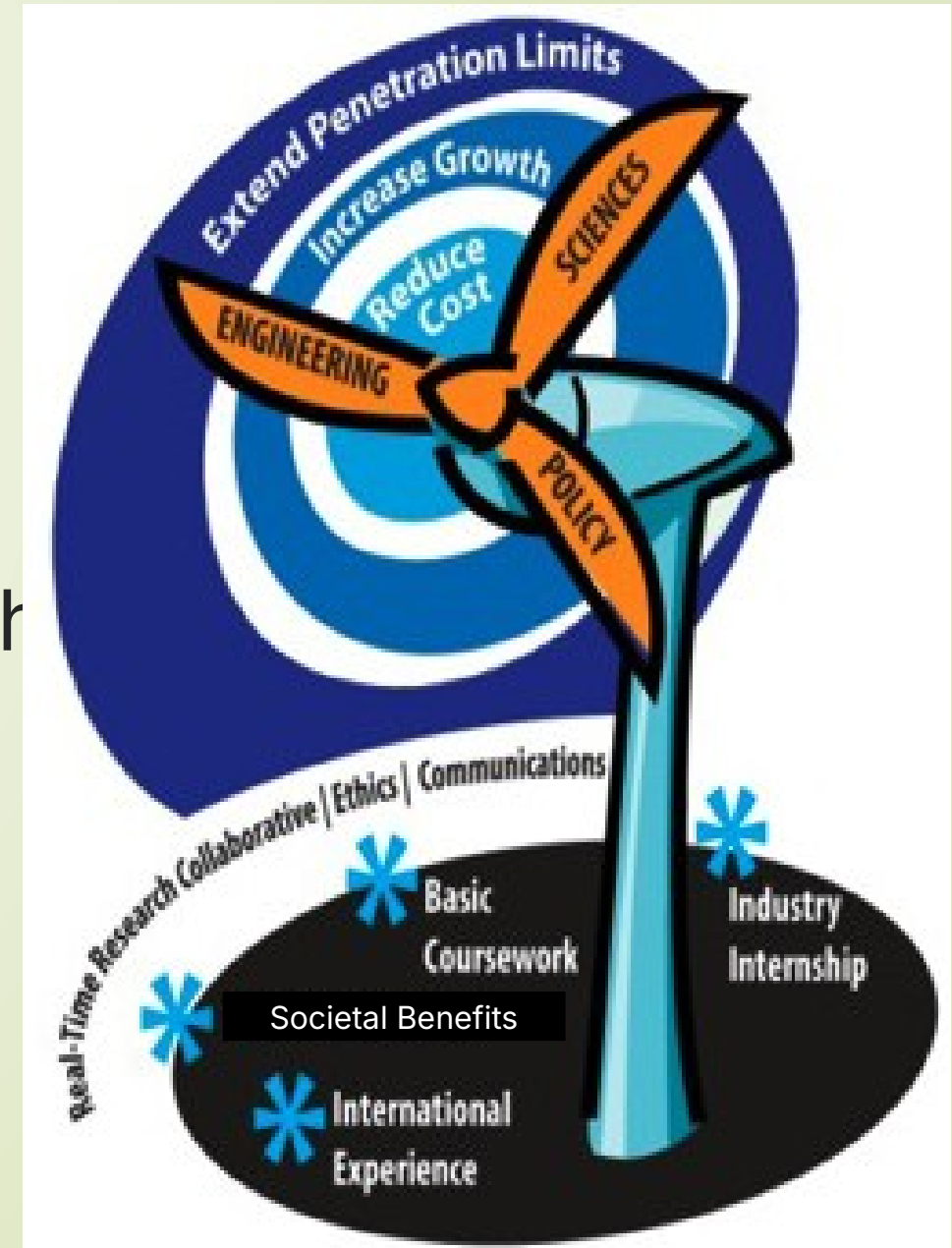
@ BINUS SCHOOL

Me & My Society & My Home
What am I there for ?
What I want to do ?
What I wish to Contribute?
What I wish to Leave behind ?
Whom I wish to be associated with

Awesome Applications to Society and Carriers

Suprit Pal Singh

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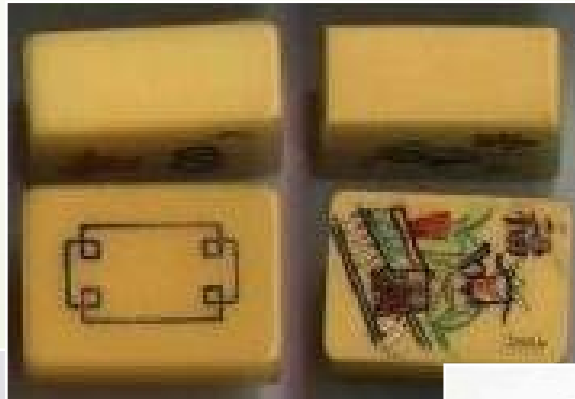
Background of Polymers

- The word plastic comes from the Greek word plastikos, meaning capable of being molded and shaped.
- Polymer comes from Greek also POLY + MER
- The earliest polymers, such as cellulose, were made from natural organic materials from animals and vegetable products.



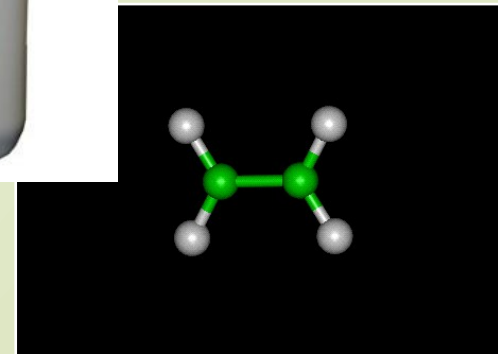
Background of Polymers

- Bakelite, the earliest synthetic polymer, is made from phenolformaldehyde, a thermoset developed in 1906.

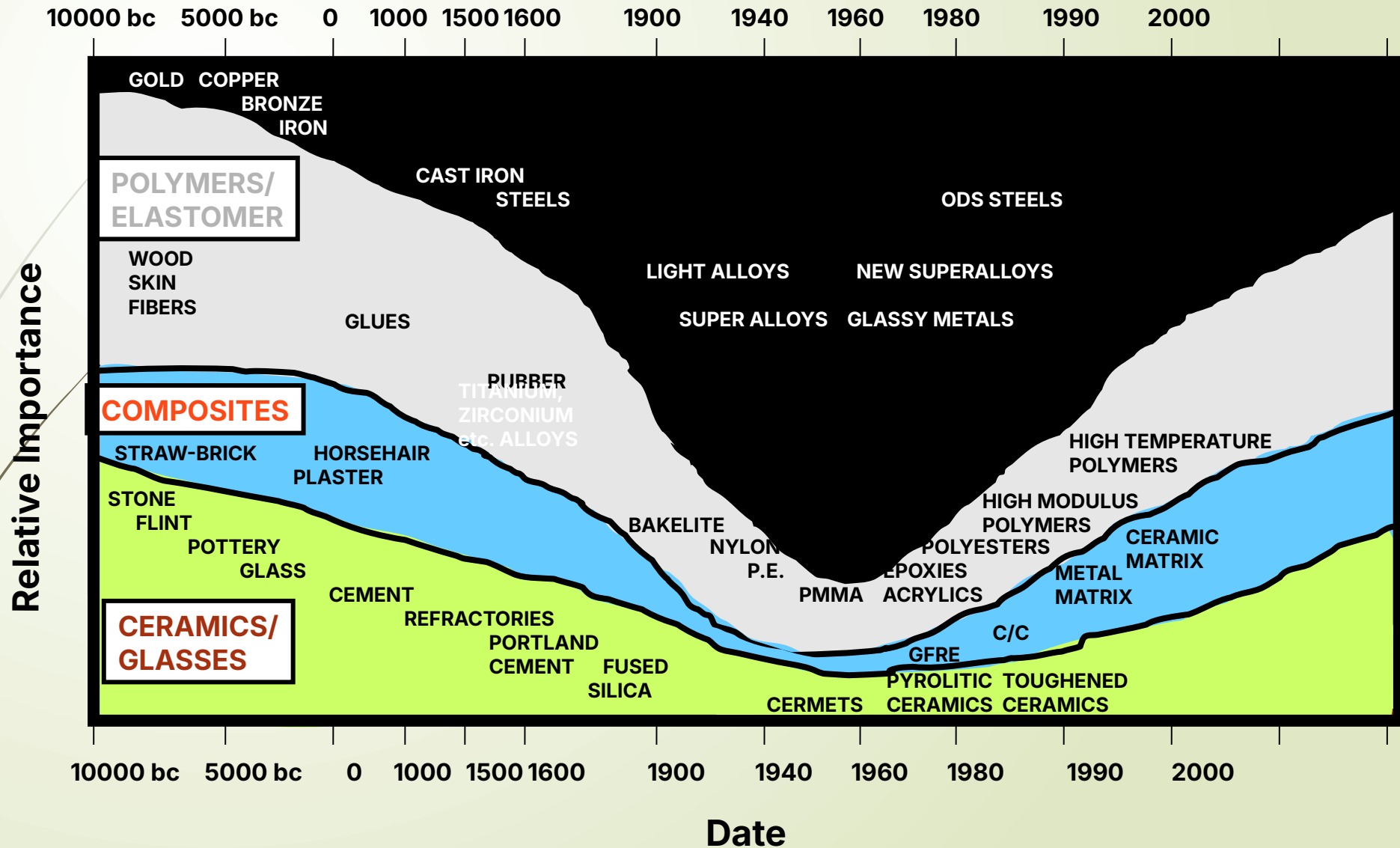


Background of Polymers

- The development of modern polymer technology began in the 1920's when raw materials necessary for making polymers were extracted from coal and petroleum products. Ethylene was the first example of such raw material.



Short History of Materials

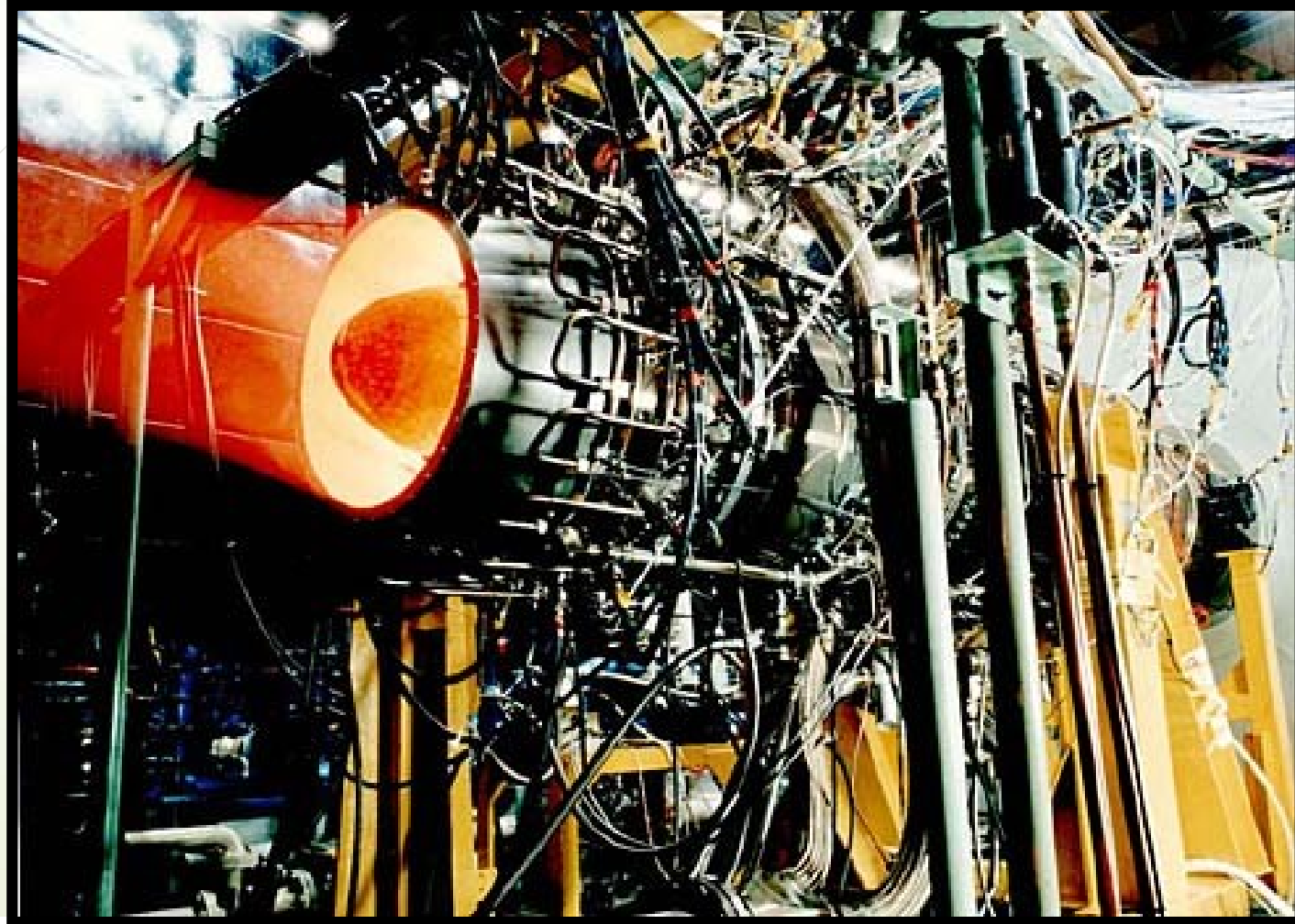


TREK Madone 5.9

Carbon Fiber Composite



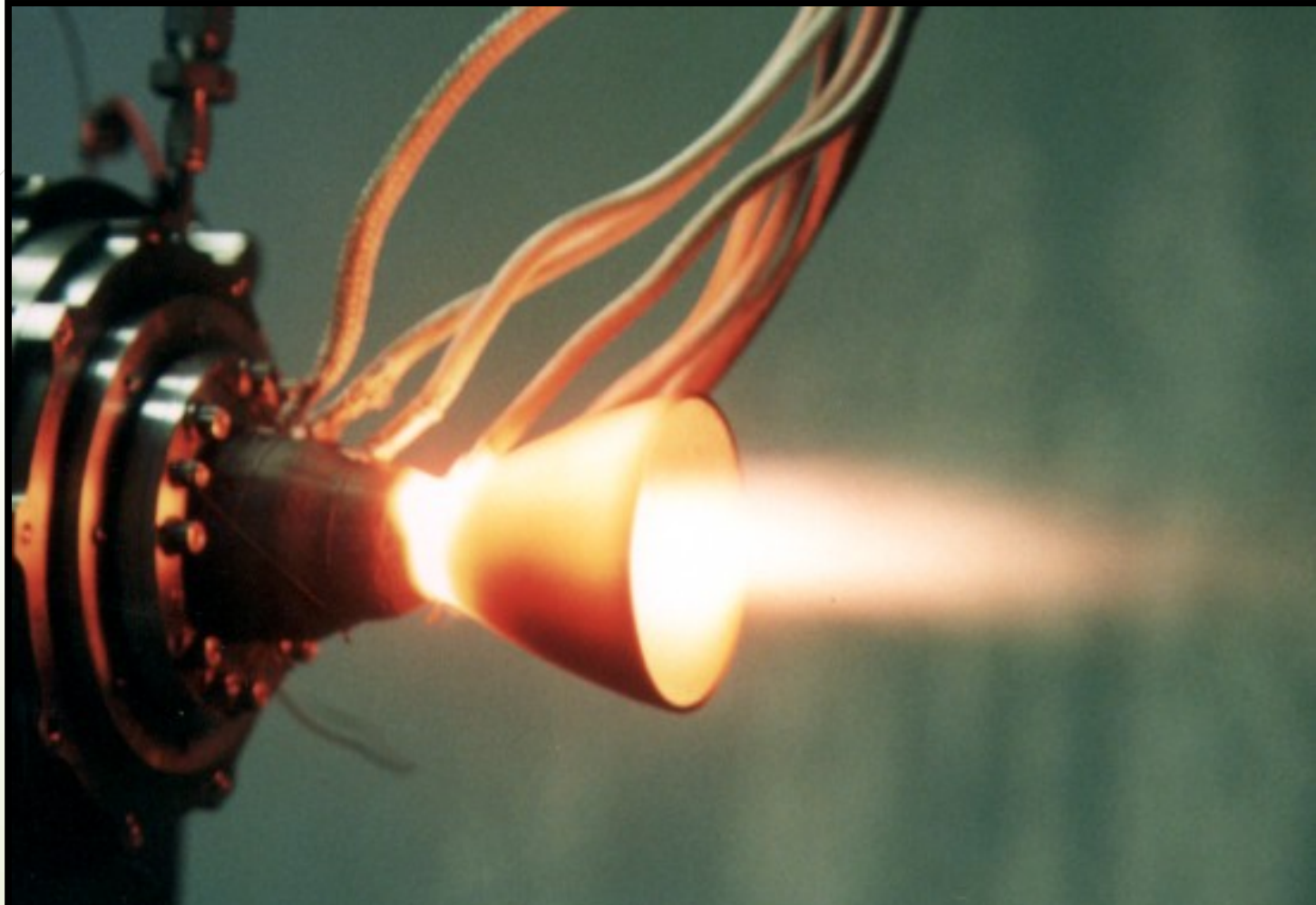
Exhaust Tail-cone



Weaving / 2D Cloth + Stitching

Successfully engine demonstrated at gas temperature 1573K (1998)

SiC/SiC Thrust chamber

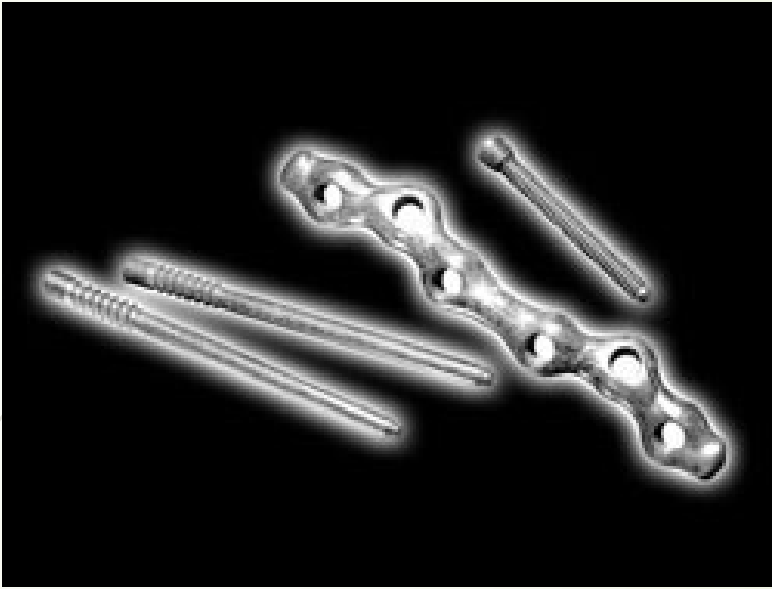


Weaving / 3-Axial Braiding

Successfully hot firing tested at gas temperature 2073K (1998)

Profiles & Applications





*Bone plates and pins molded with
Carbon Fiber Reinforced PEEK*

From :
http://www.manufacturingcenter.com/dfx/news/archive/02-07-2006/stories/1.31.06_images/601df-402b.jpg



Plaster of Paris Bandage

From :
http://image.ec21.com/image/goldenintl/timg_GC00789063_CA00789064/Plaster_of_Paris_Bandage.jpg



Carbon fiber PEEK Translaminar pins, intermedullary nails/screws, and osteosynthesis plates/screws

From: http://www.healthpointcapital.com/research/VICFixSysBlue_sm.gif



Intramedullary nail

From: <http://www.zimmer.com/web/images/products/trauma/itst01.jpg>

Composites in industry

- ▢ Engineering applications
 - ▢ Aerospace
 - ▢ Automobile
 - ▢ Pressure vessel and pipes
- ▢ Any place where high performance materials are desired



Turret Shield



Industrial Spring



Medical Table

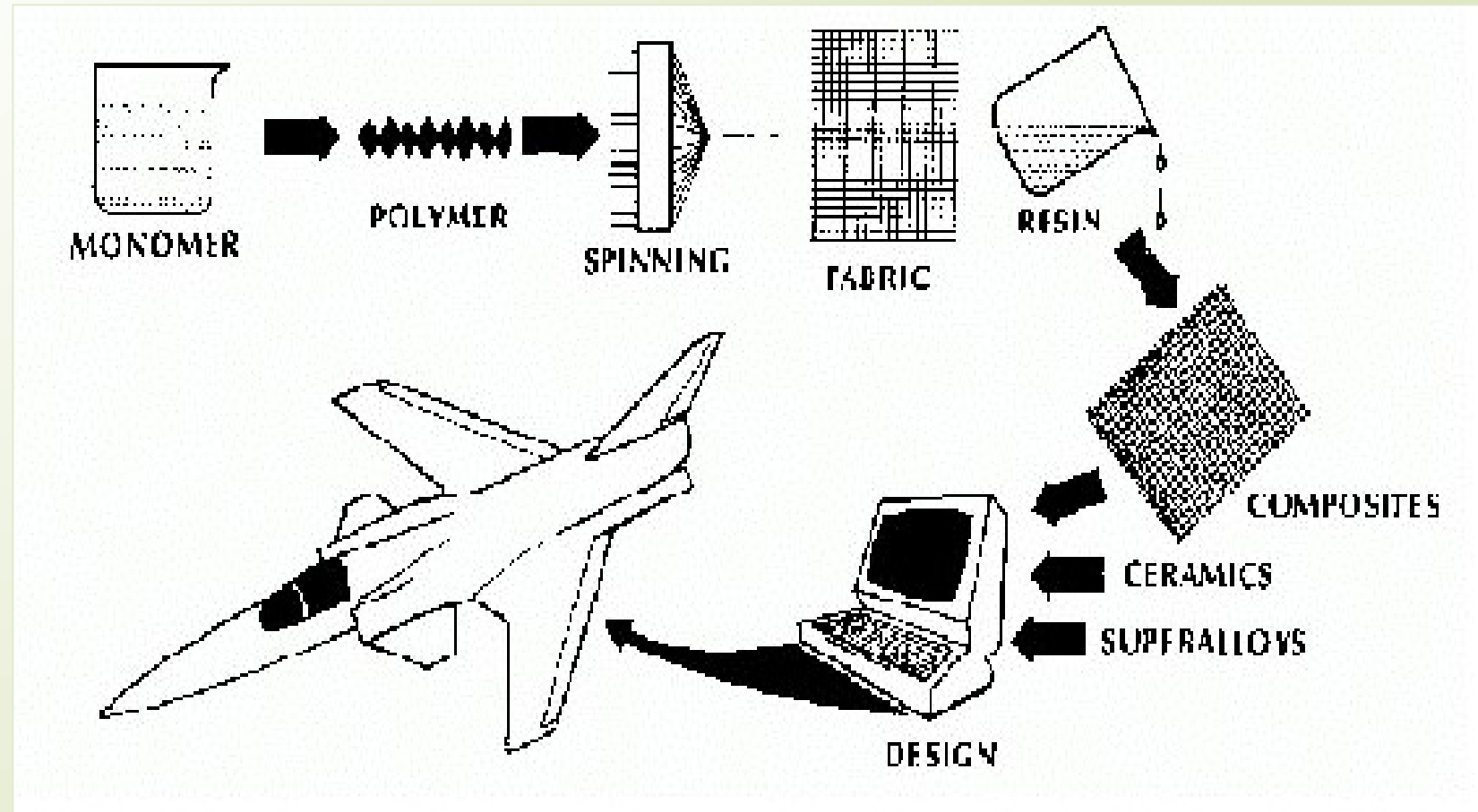
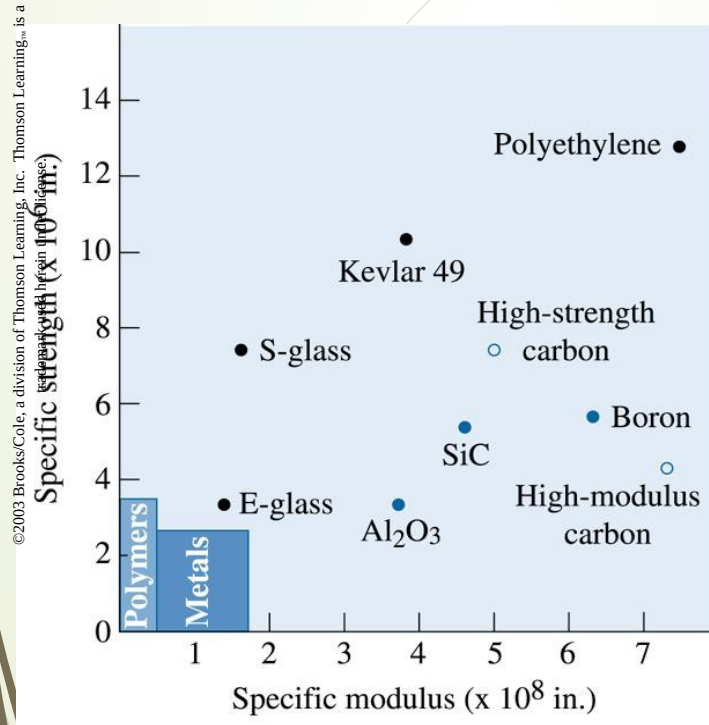


Bullet proof shields

DESIGNER MATERIALS

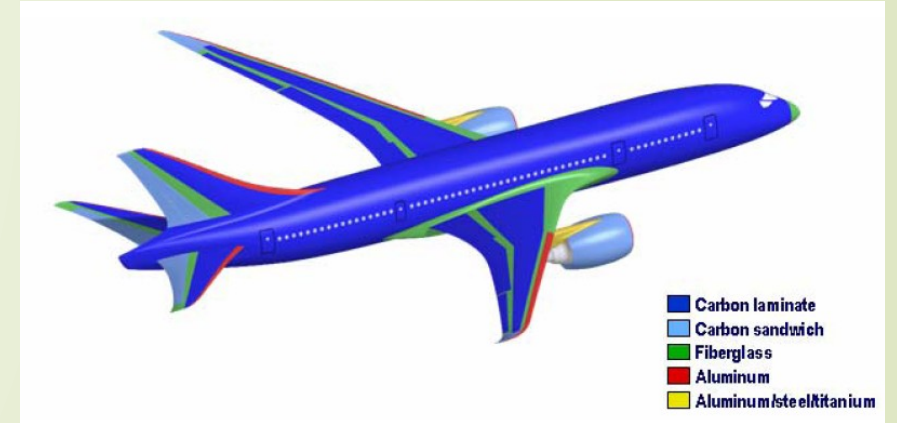
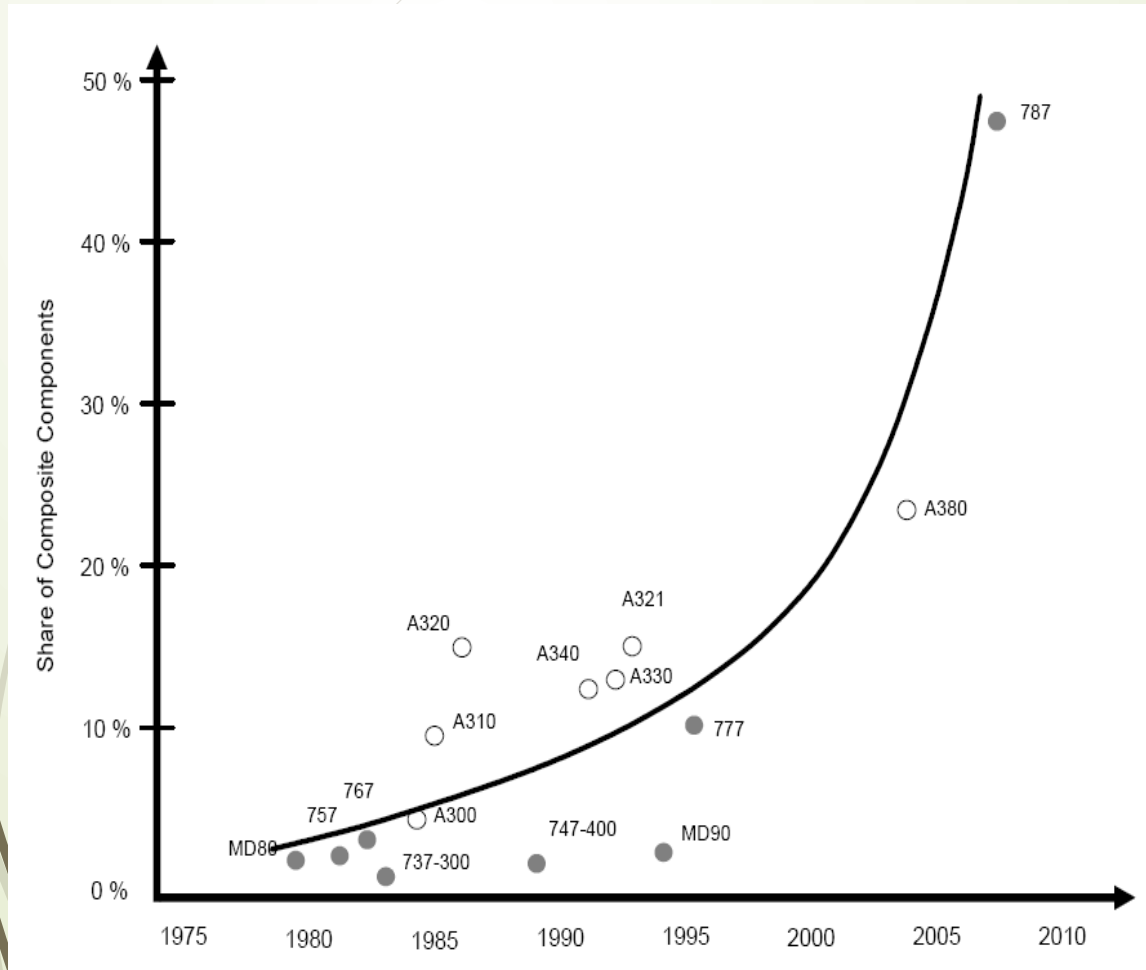
Man Playing in the Image of GOD

- Engineered Materials
- Specific Required Materials
- To Build and make



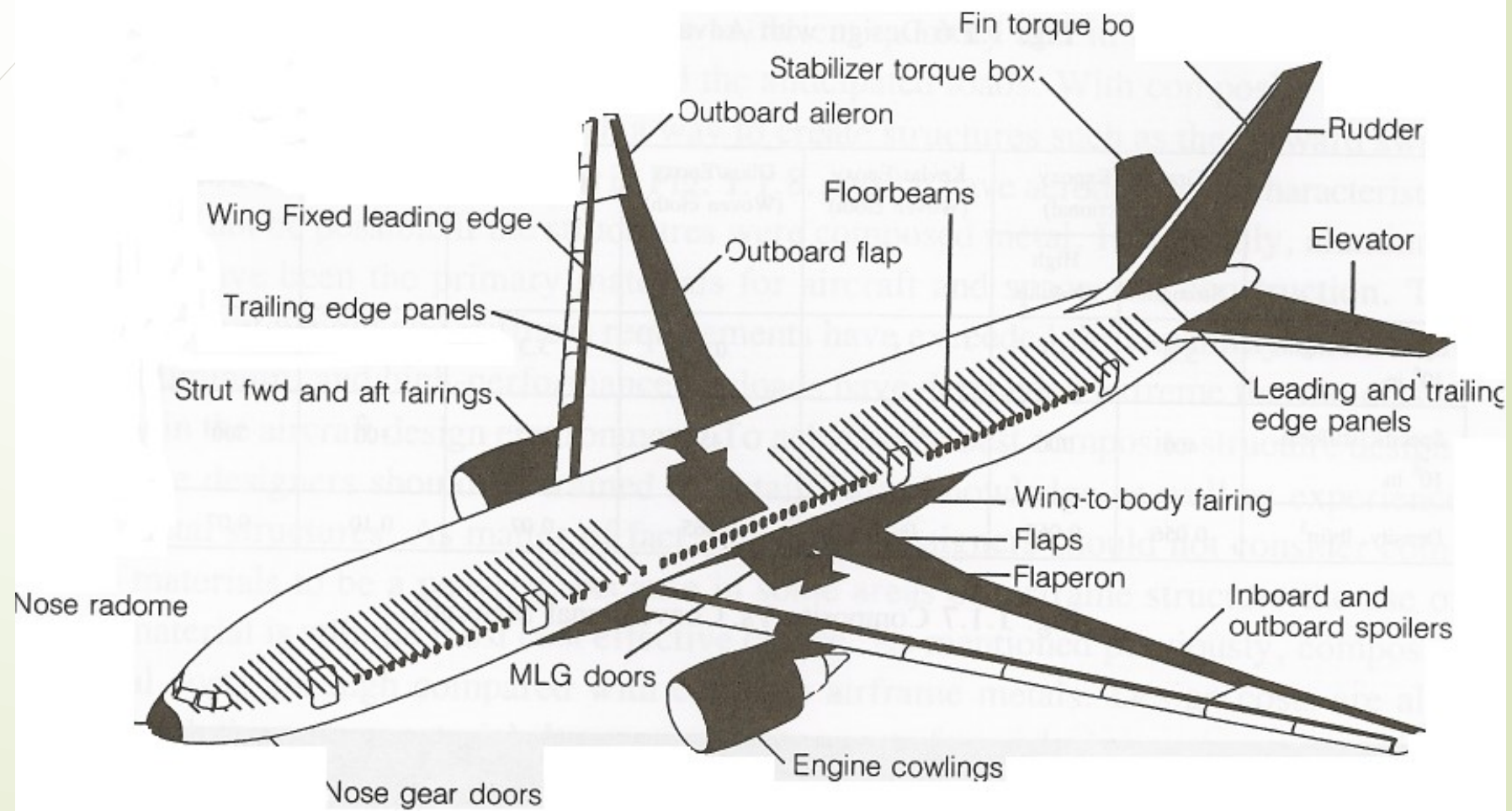
Motivation – Structural Composites

Percentage of composite components in commercial aircraft*

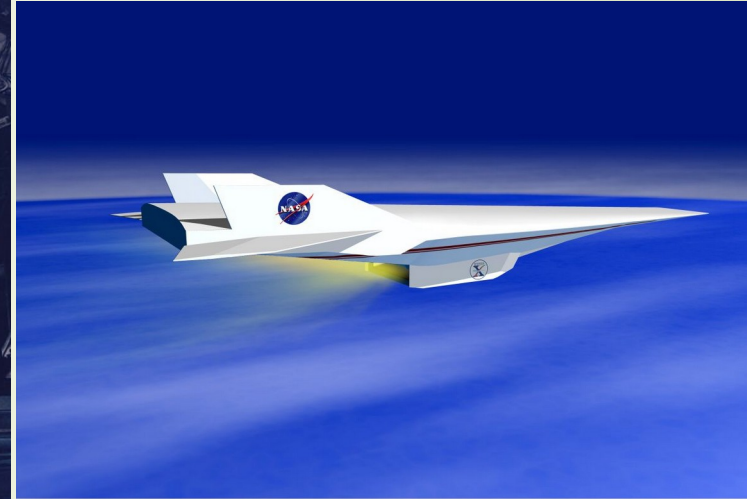


*Source: "Going to Extremes" National Academies Research Council Report, 2005

787 Design Highlights



Structural Composites in Aerospace Applications



Dryden Flight Research Center ED97 43968-03
FIRED UP: This is an artist's depiction of a Hyper-X
research vehicle under scramjet power in free-flight
following separation from its booster rocket.

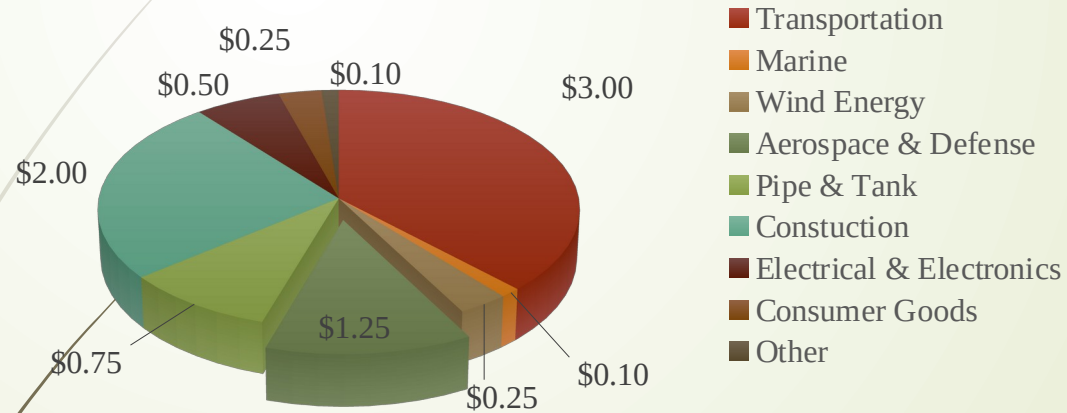
- Thermal protection system for a re-entry space vehicle:
Nose corn, leading edge, ...
- Rocket engine: Extendable nozzle, aerospike engine, ...
- Scram-jet engine for a future space vehicle.

*C/C with EBC is in commercial.
SiC/SiC will be more attractive (e.g. Tyrannohex).*

Composite Material Markets

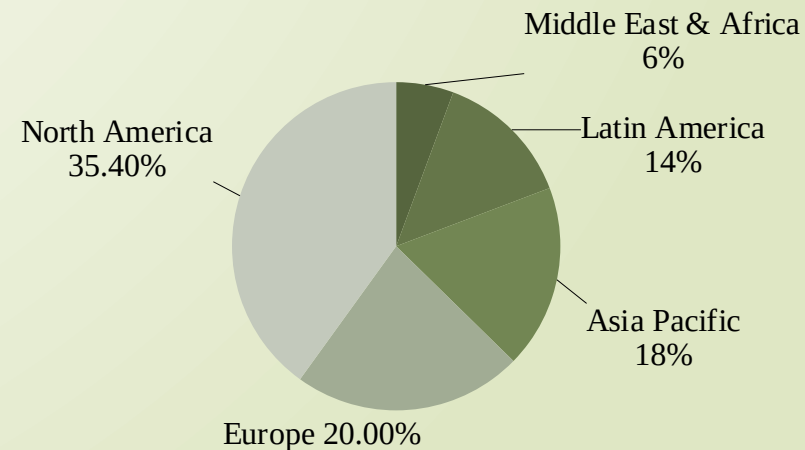
19

U.S. Composite Material Markets



- \$8.0 Billion Dollars shipped in 2016
- Since 1980, Composite Market has grown 25 times
 - Aluminum = 3 times
 - Steel = 1.5 times

Aerospace & Defense



1960's of Polymers



2015's of Polymers





Improving the life-time of dental composites

(Thiourethanes oligomers improve
properties of methacrylate-based dental
restorative materials)

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Michelle Gunness, PhD, CLP

gunnessm@ohsu.edu

Hull made of a sandwich composite
Exterior: Kevlar fiber epoxy-matrix composite
Interior: Polyvinyl chloride foam



Puye Cliff Dwelling
Anasazi Indians
1100-1580 AD



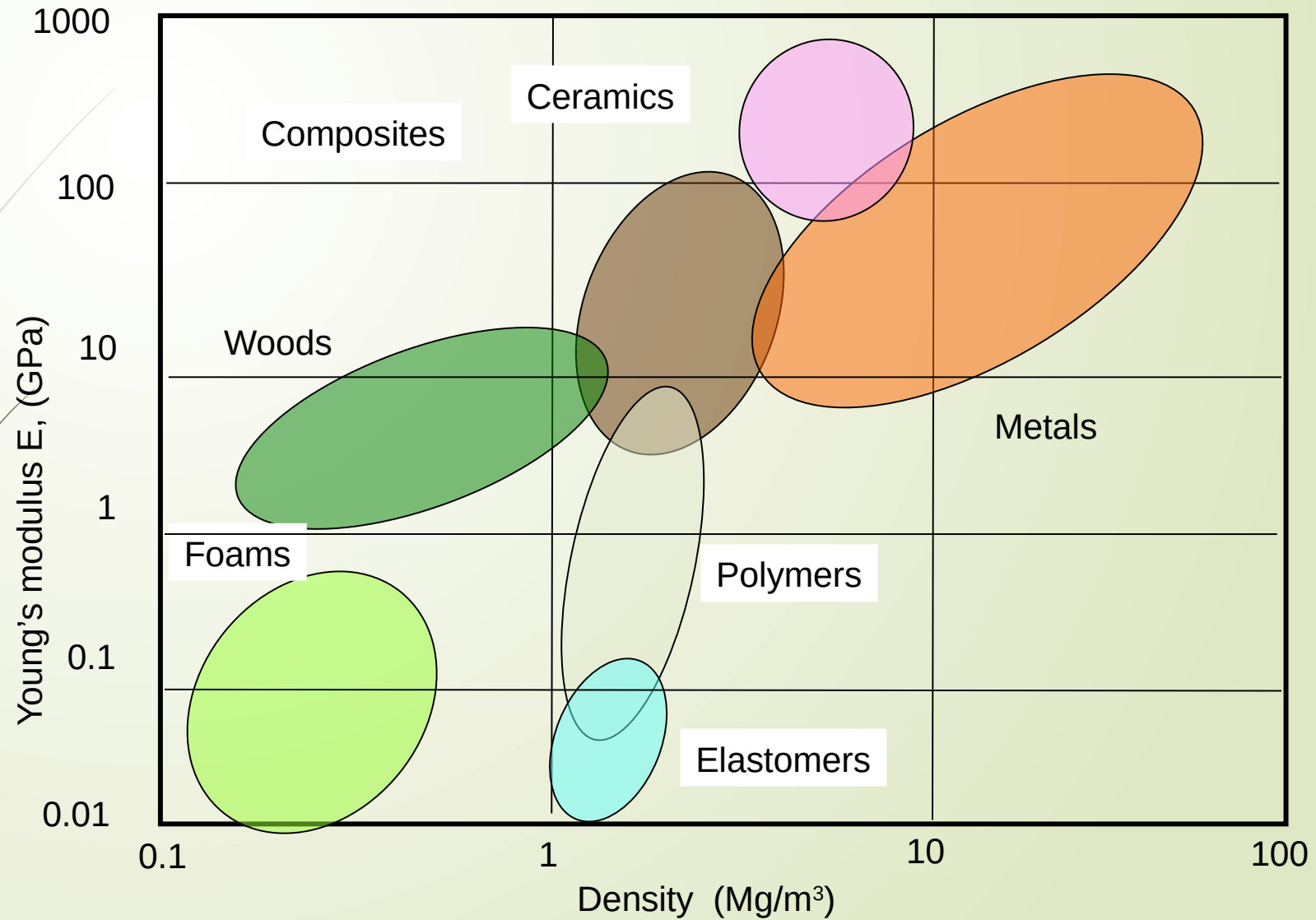


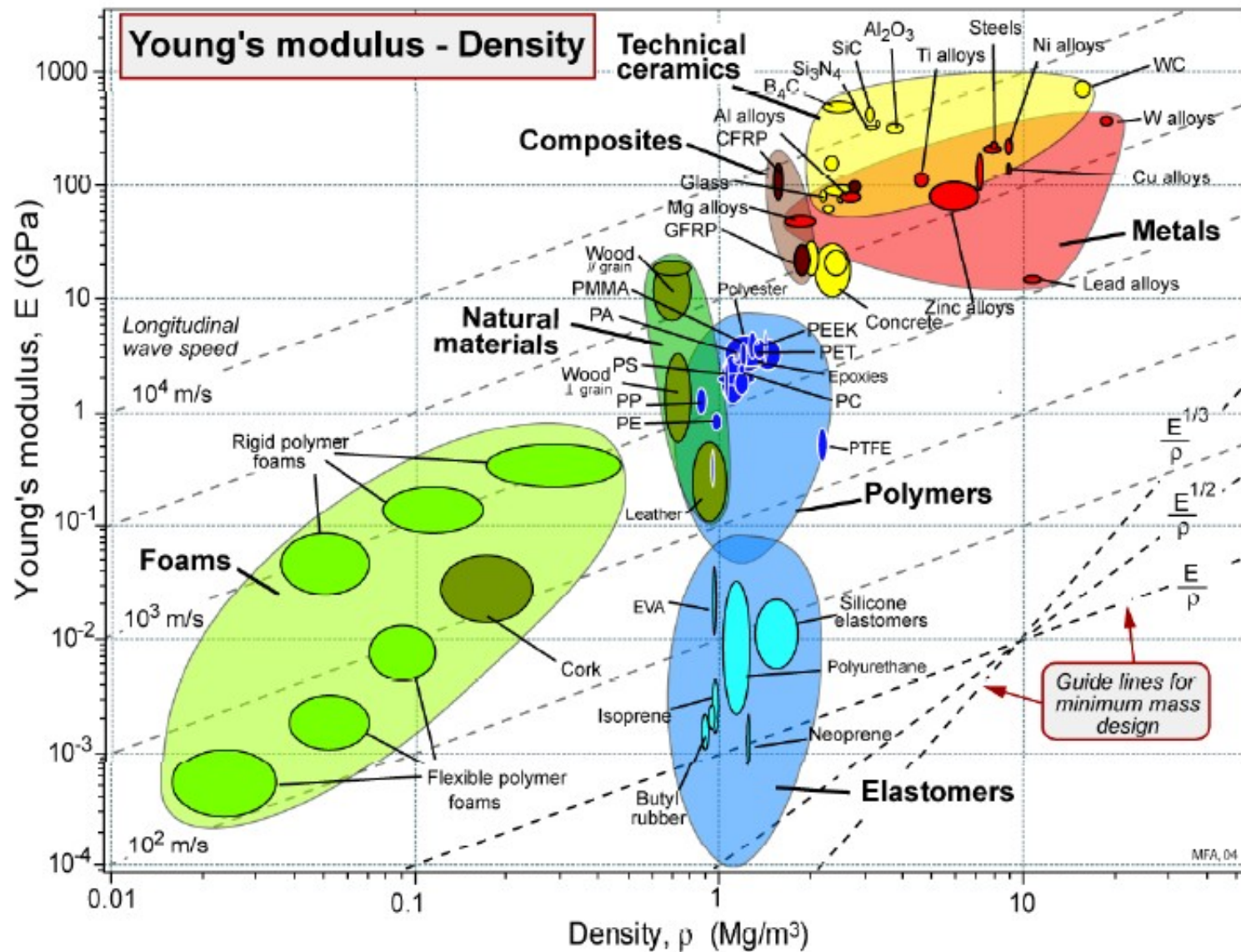
Tel-Dan Arch
~1600 BC

Fort Paramonga Chimu civilization ~1300 AD



Material property- charts: modulus - density





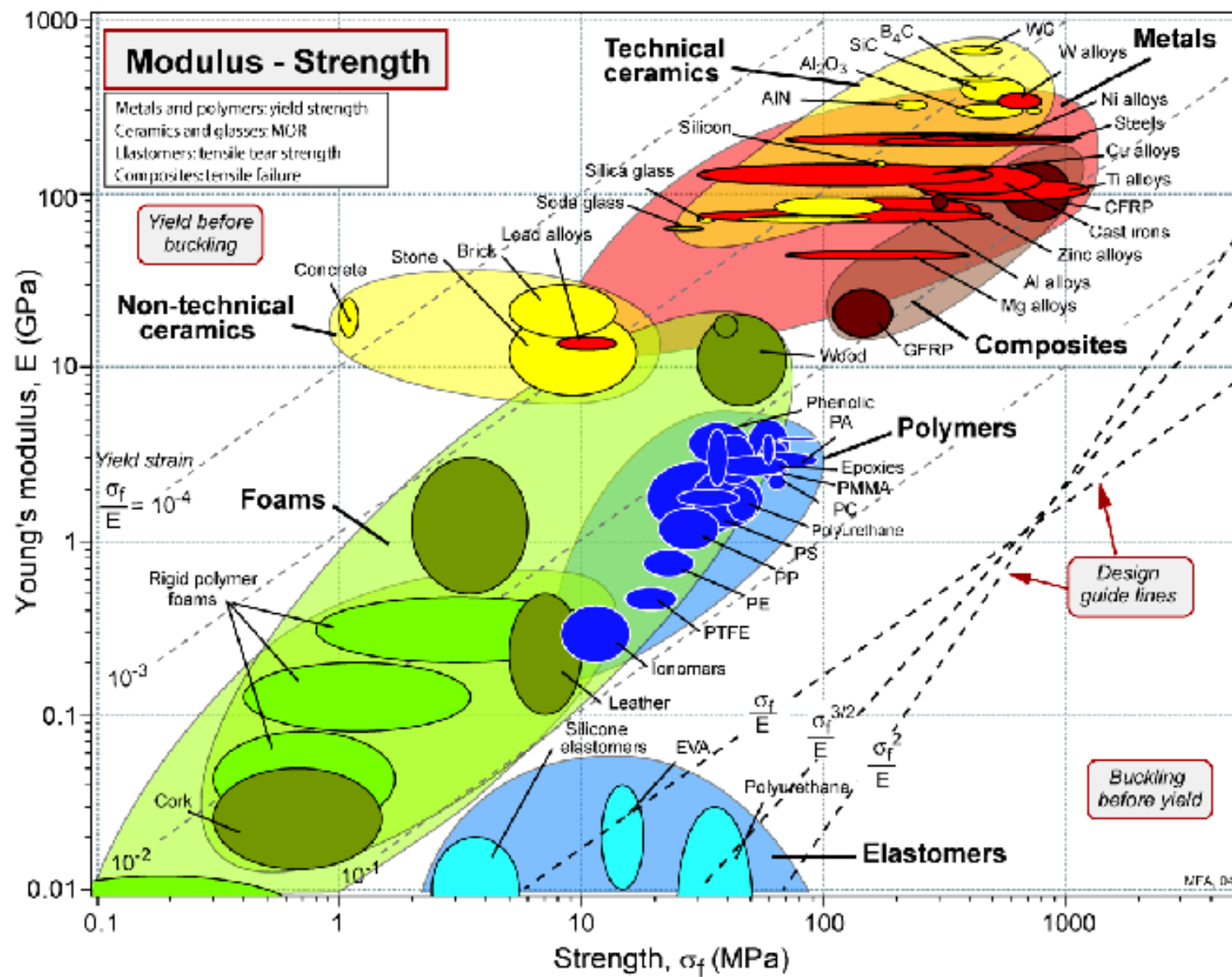
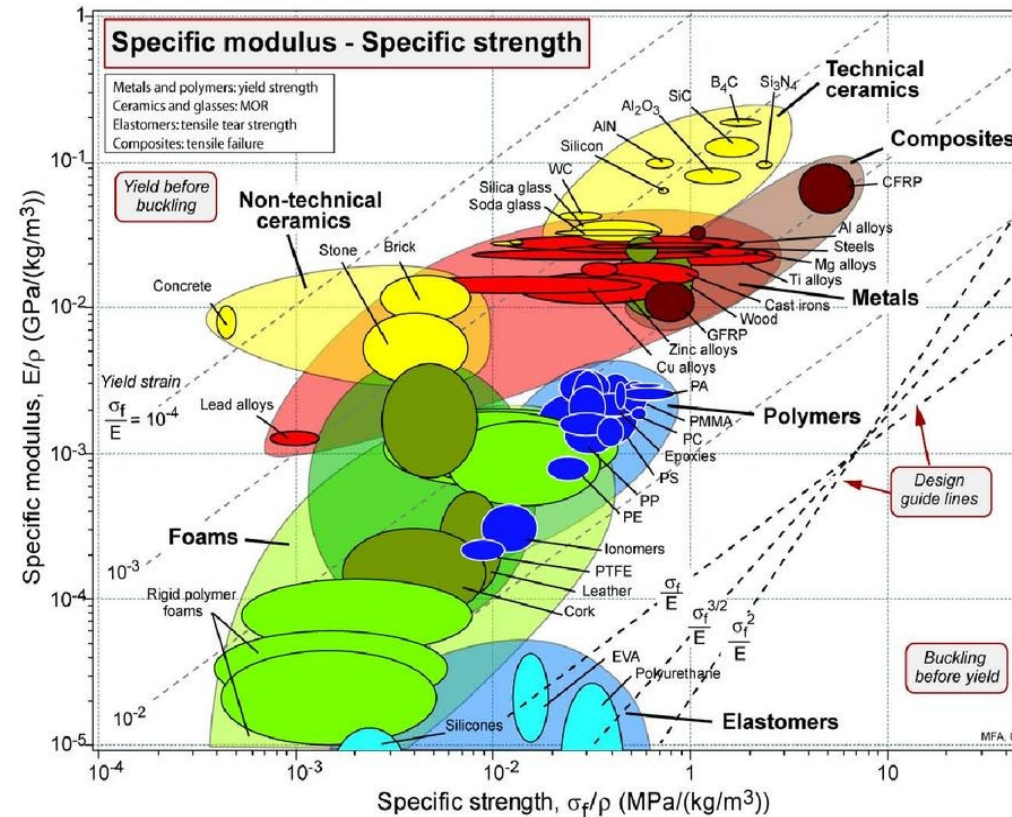


Chart 4: Specific modulus, E/ρ , against Specific strength, σ_f/ρ

The chart for specific stiffness and strength. The contours show the yield strain, σ_f/E . The qualifications on strength given for Charts 2 and 4 apply here also. The chart finds application in minimum weight design of ties and springs, and in the design of rotating components to maximize rotational speed or energy storage, etc. The guide lines show the loci of points for which

- (a) $\sigma_f^2/E\rho = C$ (ties, springs of minimum weight; maximum rotational velocity of disks)
- (b) $\sigma_f^{2/3}/E\rho^{1/2} = C$
- (c) $\sigma_f/E = C$ (elastic hinge design)

The value of the constant C increases as the lines are displaced downwards and to the right.



Profiles & Applications



4. Profiles & applications (examples)

- Conduit rods used in telecom
- Cable ladders
- Handrails
- Components used in wind blades
- Telescopic tubing
- Antenna radomes
- Specialised piping/tubes



Profiles & Applications



Glass Fiber Reinforced Composites



Ferrari 308 GT4

Glass Fiber Composite

Reinforced Concrete Composite



Steel reinforced "rebar"

Carbon Fiber/epoxy rod

Reinforced Fired Adobe Composite



Reinforced Fired Adobe Composite

Inca city ~ 1500 AD

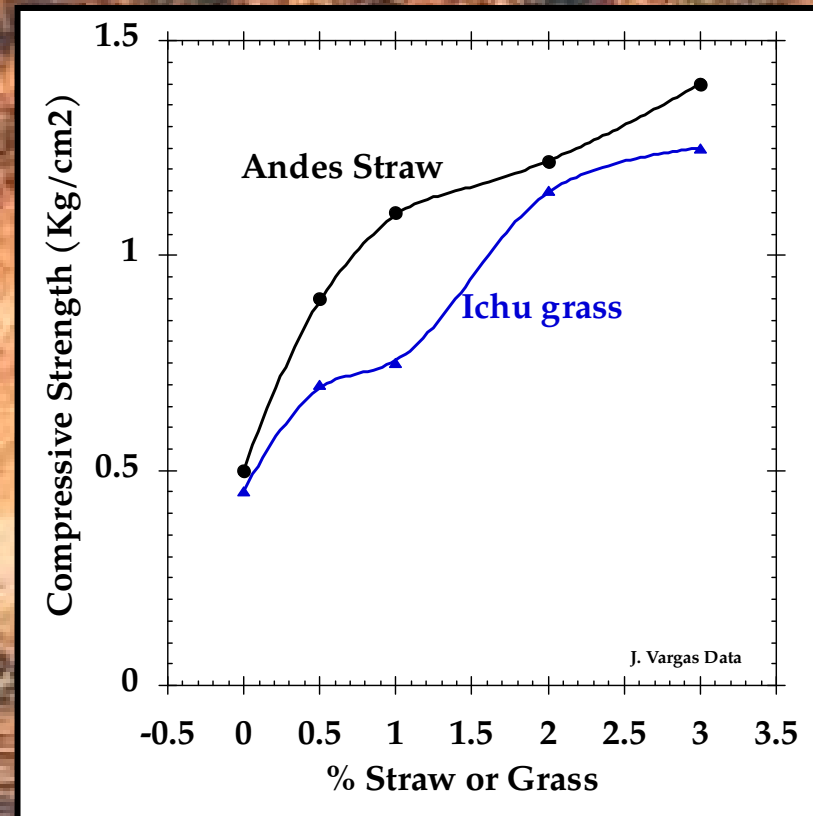
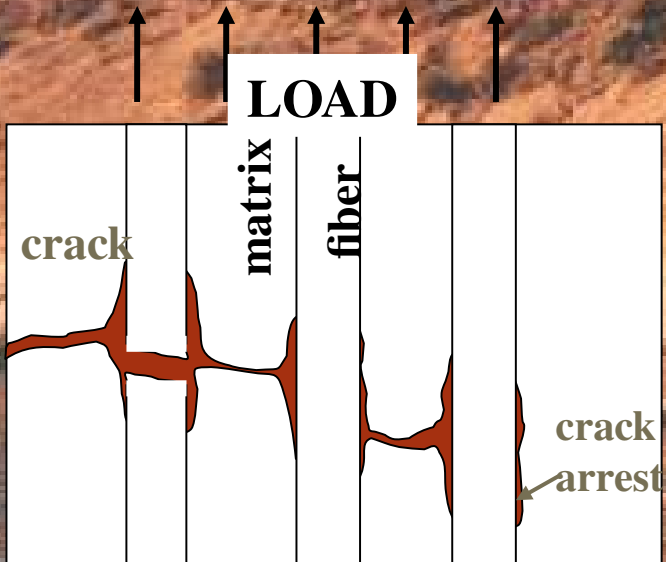
Present Day



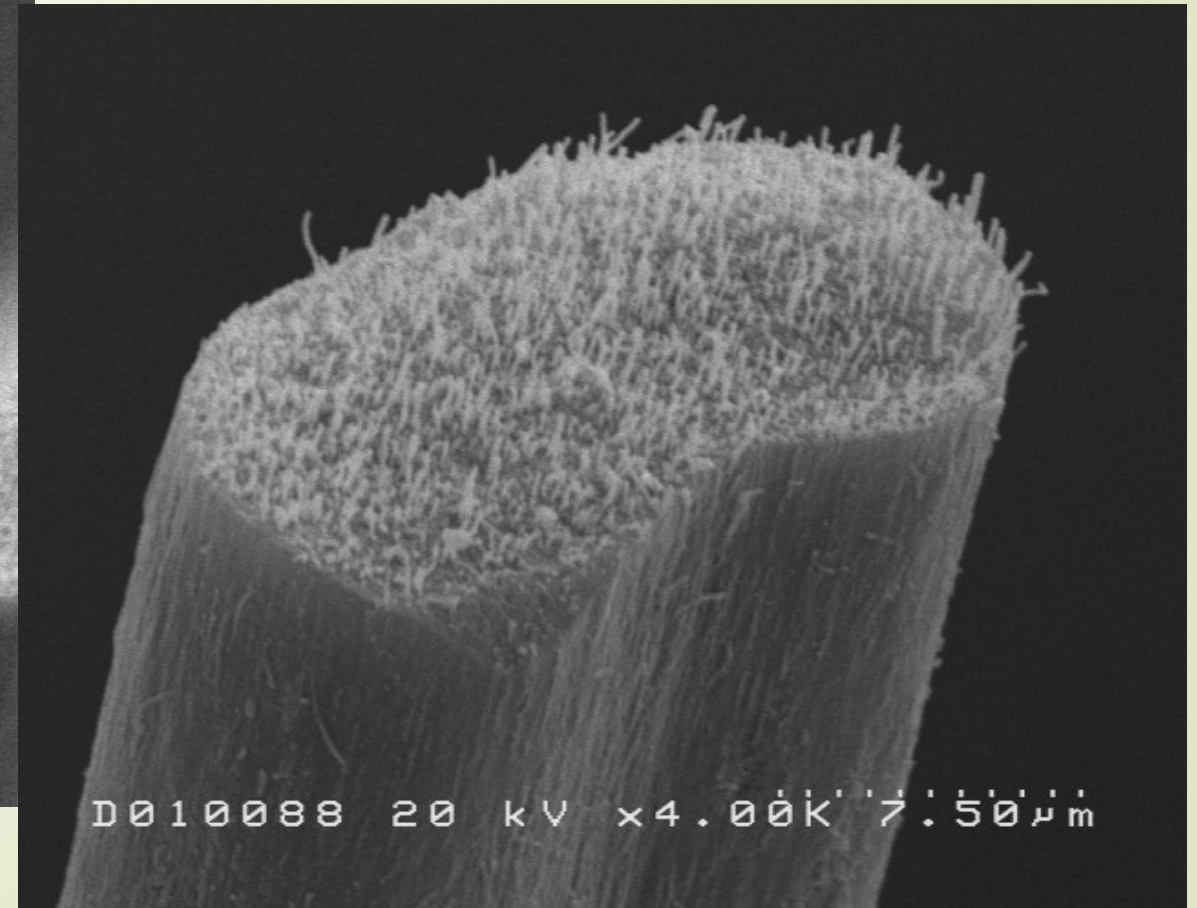
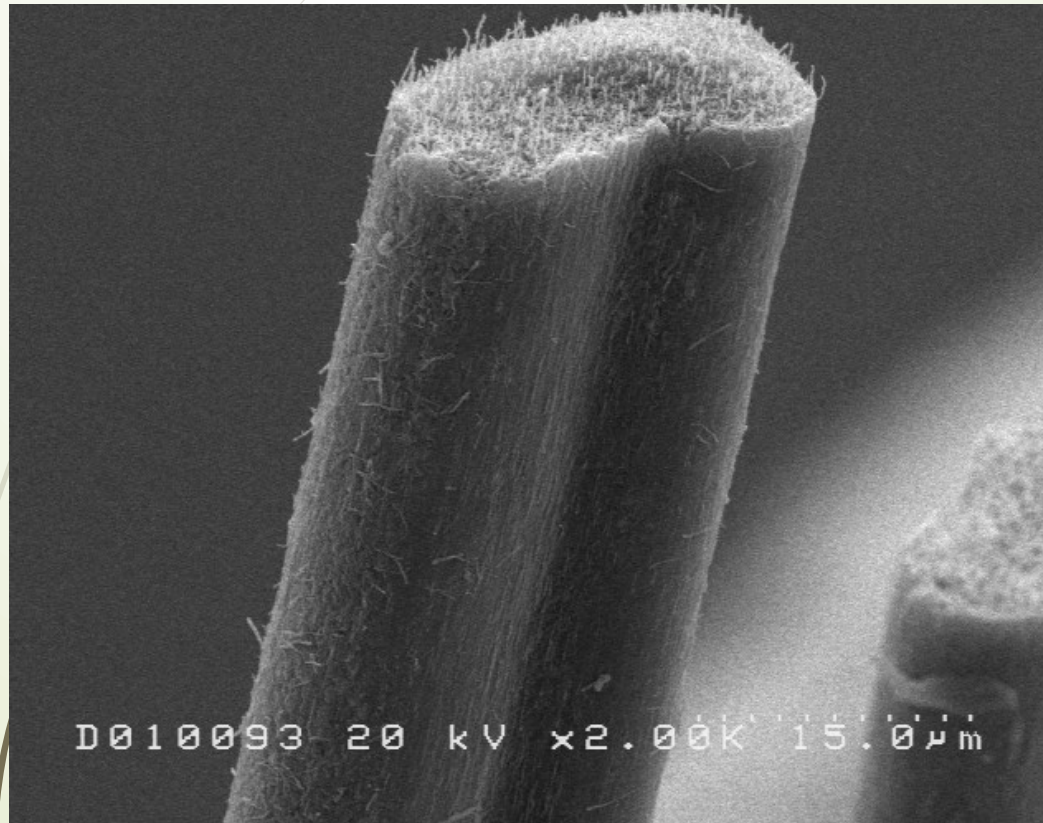
Reinforced Fired Adobe Composite

Inca city ~ 1500 AD

Present Day



20 wt% MWNT/Carbon Fiber >100GPA



Carbon Fiber:

- PAN (polyacrylonitrile) based carbon fiber
 - Commercial use for general purpose.
 - Varieties: high strength, high modulus, long elongation, ...
- Pitch based carbon fiber
 - High performance carbon fiber: Anisotropic, **high graphitization**.
Tensile strength: 2.3~4.0GPa, Tensile modulus: 400~900GPa
 - General purpose (low cost) carbon fiber: Isotropic microstructure.
Tensile strength: 0.6~1.0GPa, Tensile modulus: 30~60GPa

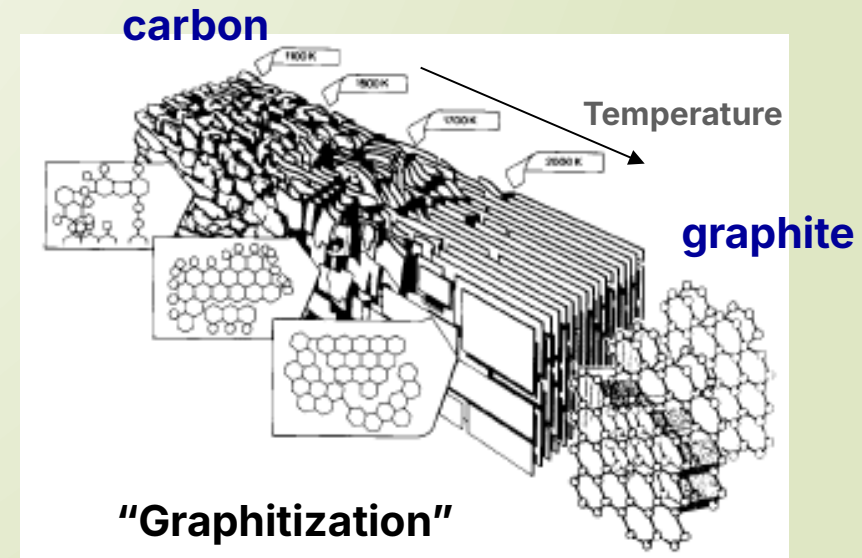
Carbon Matrix:

- Chemical vapor deposition (CVD)
- Impregnation and pyrolysis using resin or pitch.

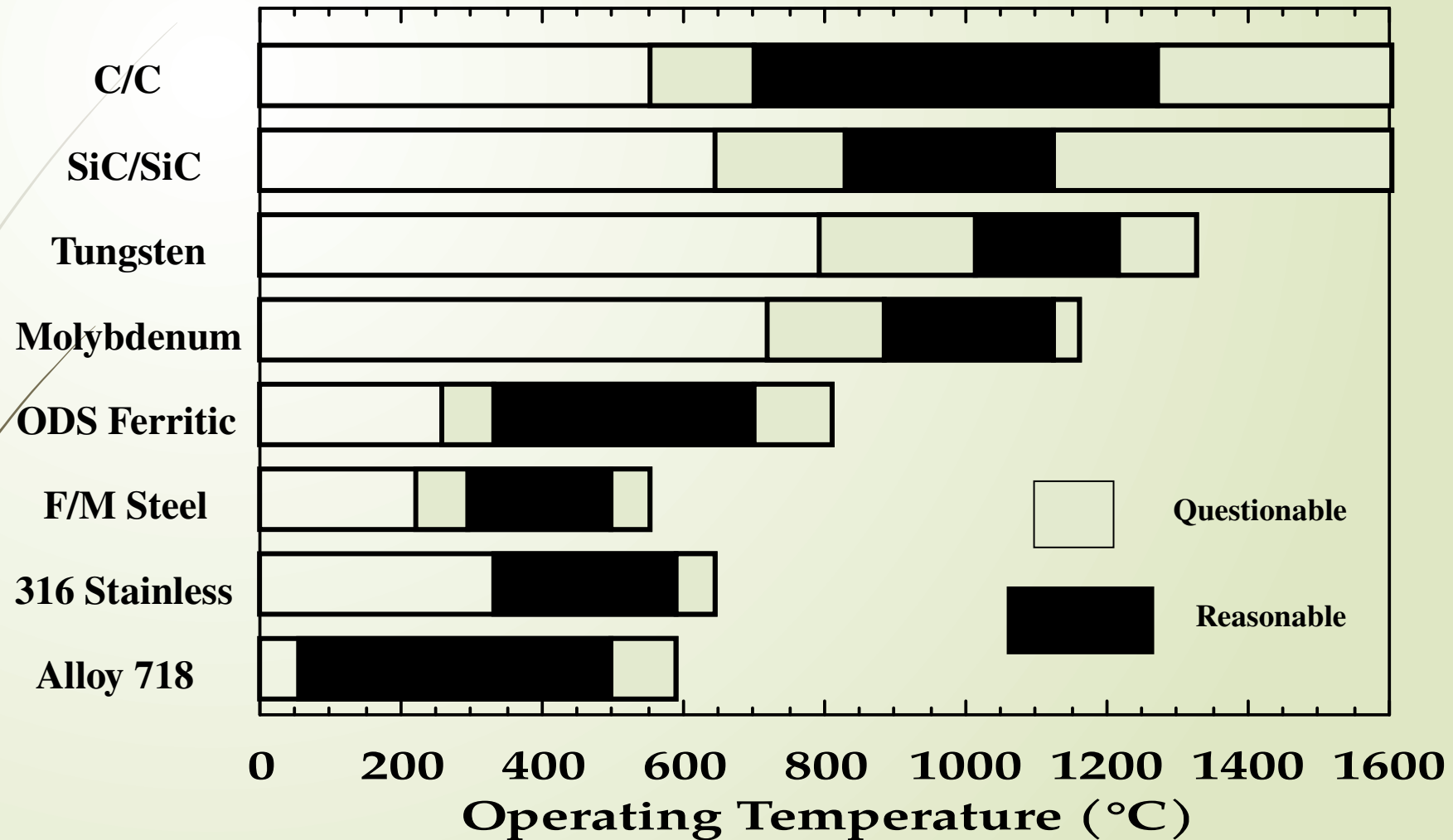
Environmental Barrier Coating:

Concern about high reactivity to oxidative products.

- Boron based glasses (<1000°C)
- Silicon carbide (<1500°C)



Operating Range, Highly Irradiated Structural Materials





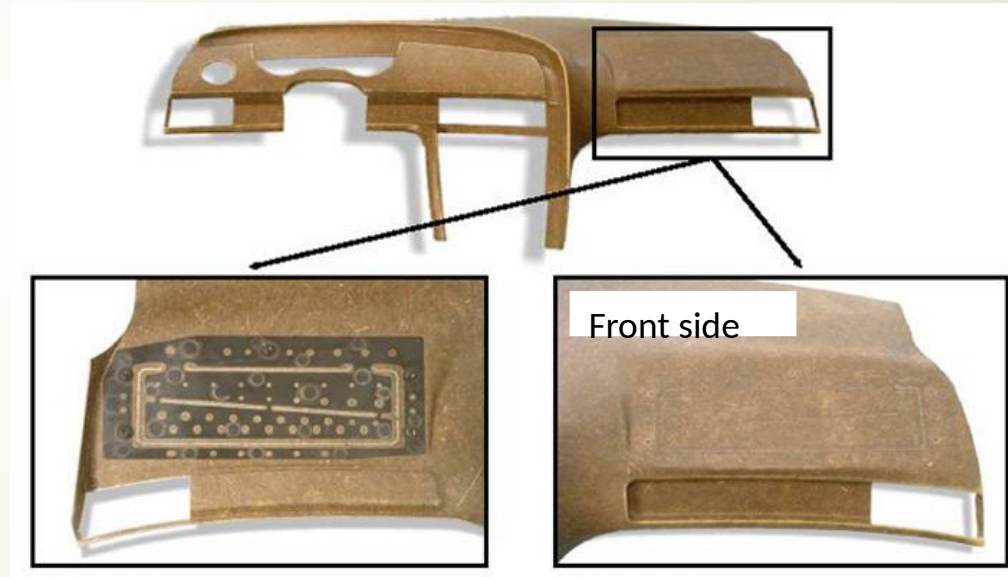
Automotive applications
Mercedes-Benz Class S with environmental certificate
Components made from different bio fibre reinforced
composites



Under floor protection trim of Mercedes A class made from banana fibre reinforced composites (Source: DaimlerChrysler Awarded for Banana Fibre Use in Mercedes A Class <http://www.netcomposites.com/news.asp?2888>)



Automotive interior components made from wood fibre reinforced composites (Source: Bledzki et al., Cars from Bio-Fibres, Macromolecular Materials and Engineering, 2006, 291, 449-457)



Back side with air bag sheet

Front side

Automotive instrumental panel with integrated airbag flap made from bio-fibre reinforced composites (Source: Bledzki et al., Cars from Bio-Fibres, Macromolecular Materials and Engineering, 2006, 291, 449-457)

Wood Flour — A World of Opportunities



THERMOPLASTICS

**Wood
Filled PP**

Wood Filled PP Products



'Plastics Steel' Die Drawing Makes From Wood Filled PP

Material	Flexural Strength (MPa)	Flexural Modulus
PP	48	1860
Wood	96	8946
O-PP	276	7585
EOW-PP	138	7585

Ram extrusion of PP / wood filled creates light weight wood-like material, even stronger than wood





◆ Intramedullary Nail

- ✕ Used to fix long bone fractures i.e. fracture of femoral neck
- ✕ It is inserted into the intramedullary cavity of the bone & fixed in position using screws, rods & pins
- ✕ The most successful application of bioresorbable implant
- ✕ Example-glass fiber/PEEK

◆ Total Hip Replacement (THR) & Total Knee Replacement (TKR)

- ✕ Example- reinforced UHMWPE with carbon fiber or UHMWPE itself

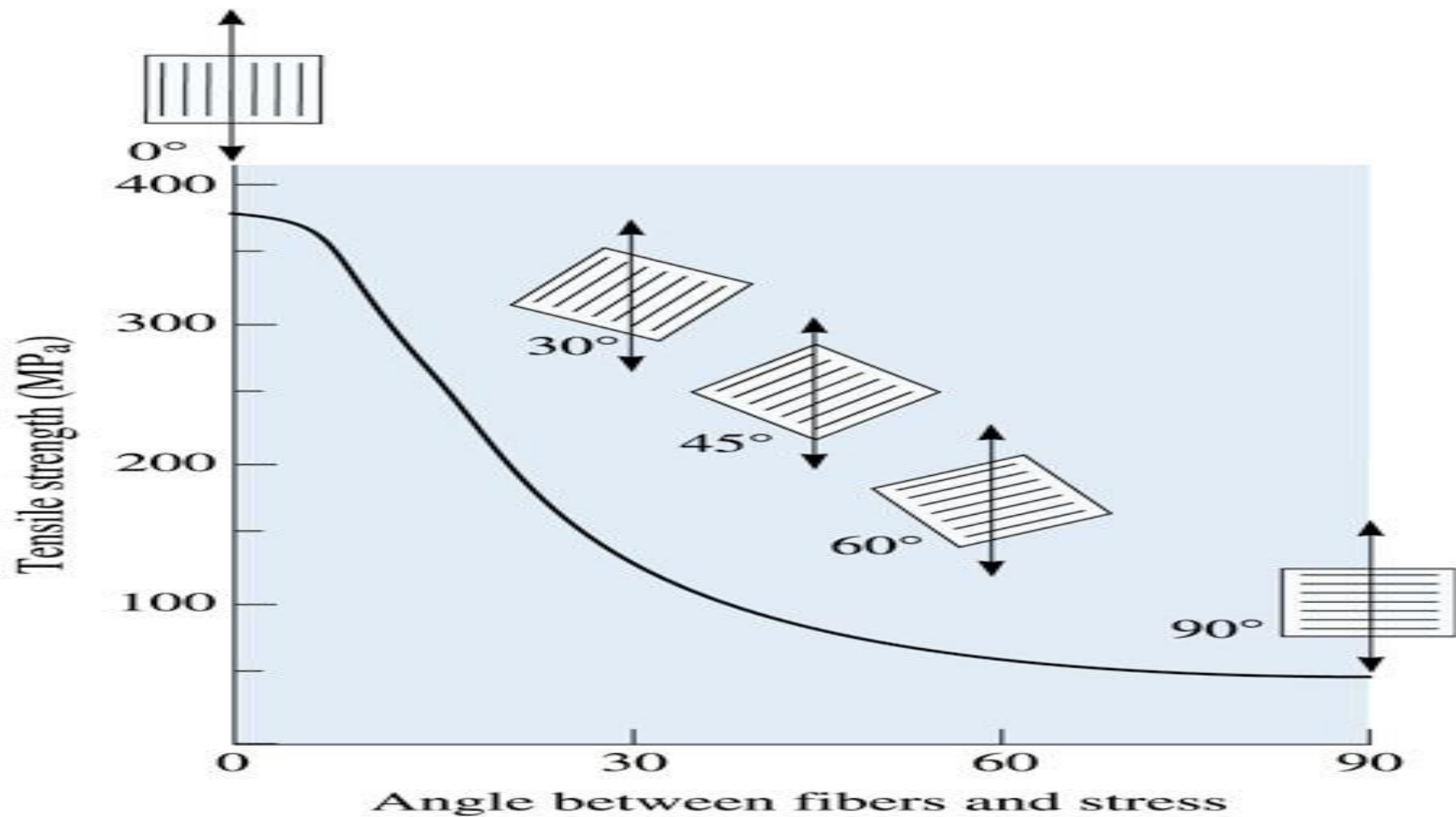
◆ Dental Applications

- ✕ Dental post is used to reinforced the remaining tooth structure on which the core and crown are built
- ✕ Example-short glass fiber reinforced polyester & carbon fiber reinforced epoxy composites
- ✕ Dental implant-artificial tooth replacing teeth permanently
- ✕ Example-Carbon fiber/carbon

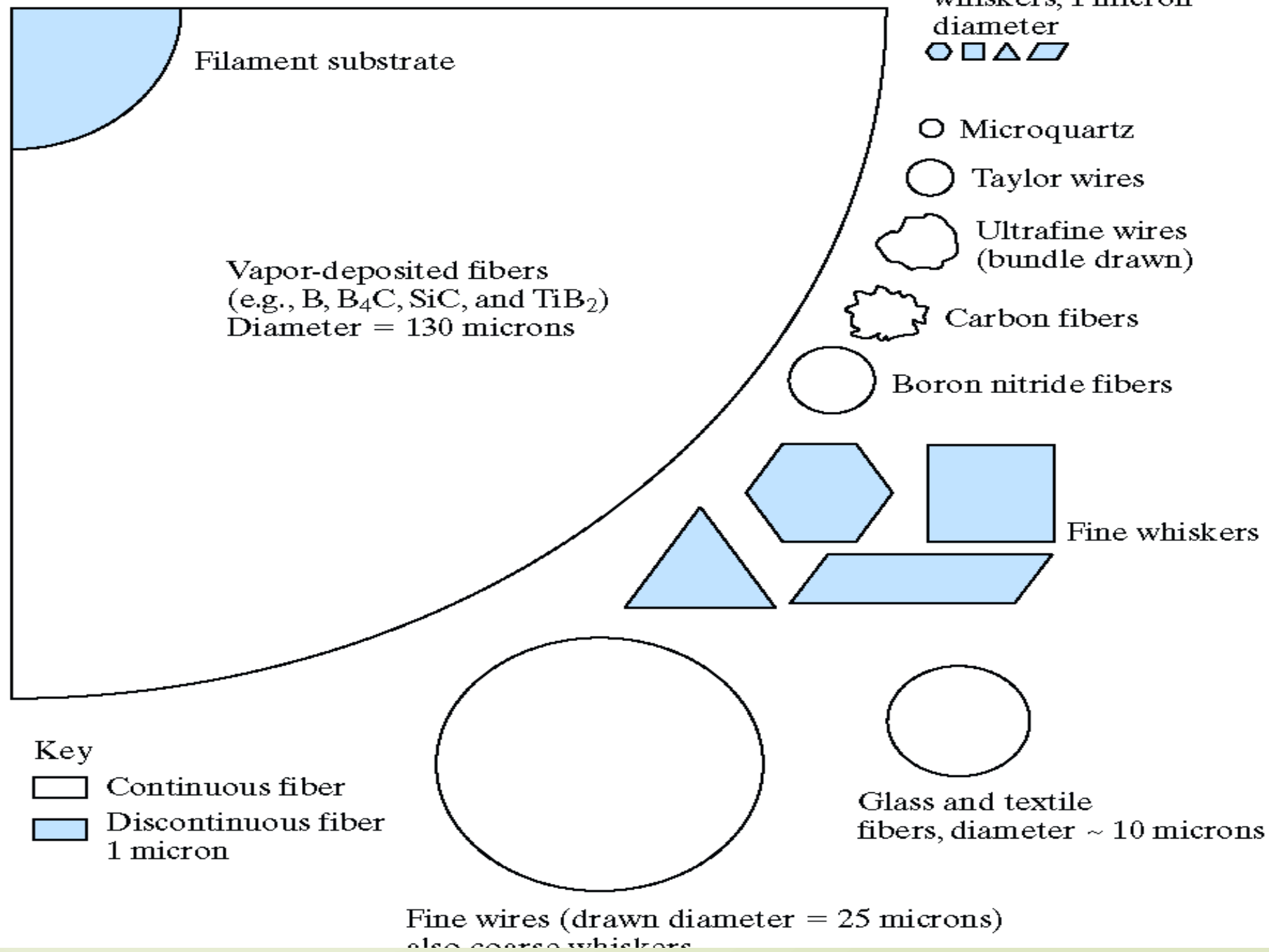
Key Characteristics of SiC(-based) Fibers

SiC Fiber	C/Si Atomic Ratio	Oxygen Content (wt%)	Tensile Strength (GPa)	Tensile Modulus (GPa)	Elongation (%)	Density (g/cm ³)	Diameter (μm)
Tyranno SA Gr.3	1.07	<0.5	2.6	400	0.6	3	7
Hi-Nicalon Type-S	1.05	0.2	2.6	420	0.6	3.1	11
Hi-Nicalon	1.39	0.5	2.8	270	1.0	2.74	14

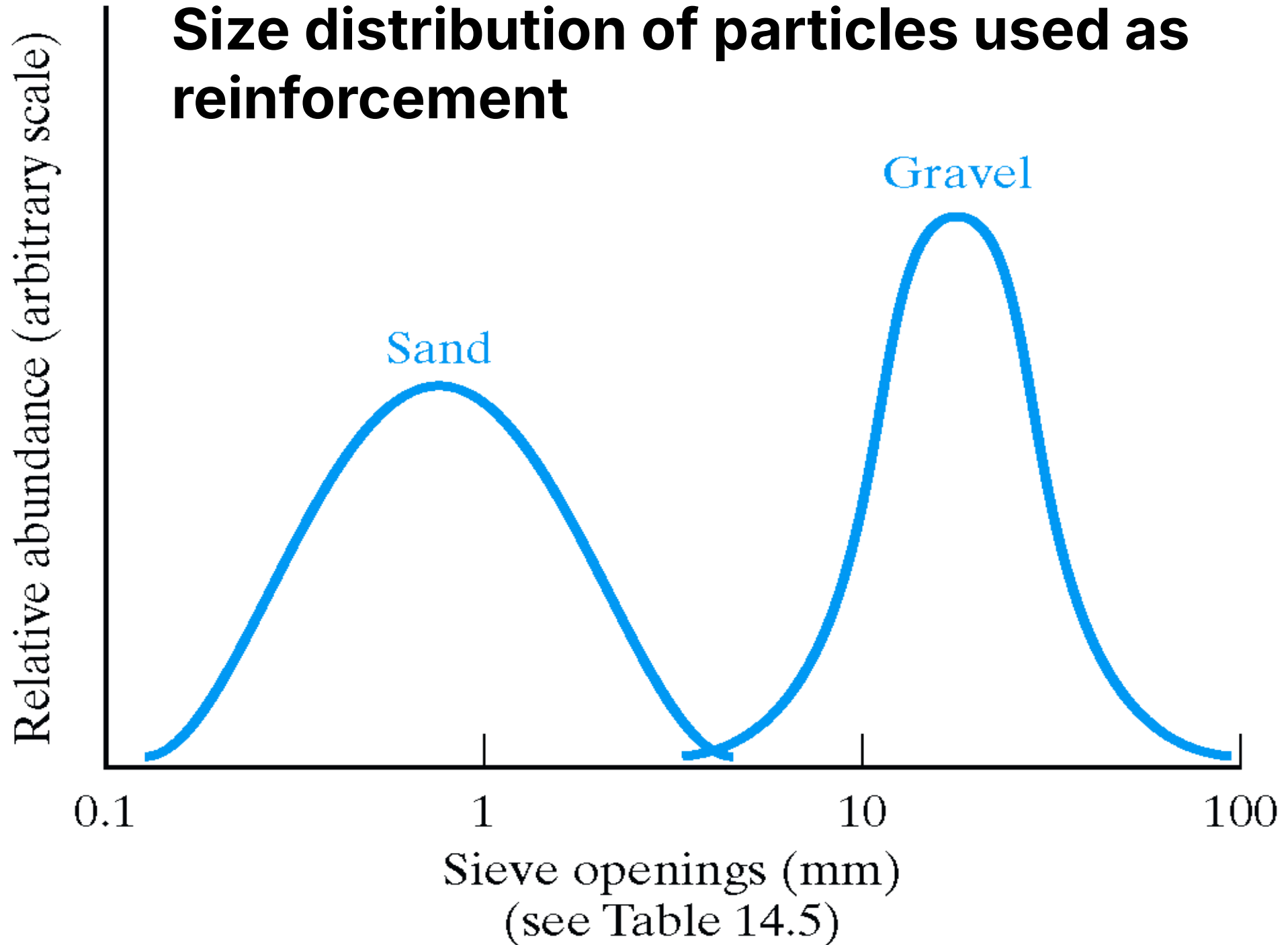


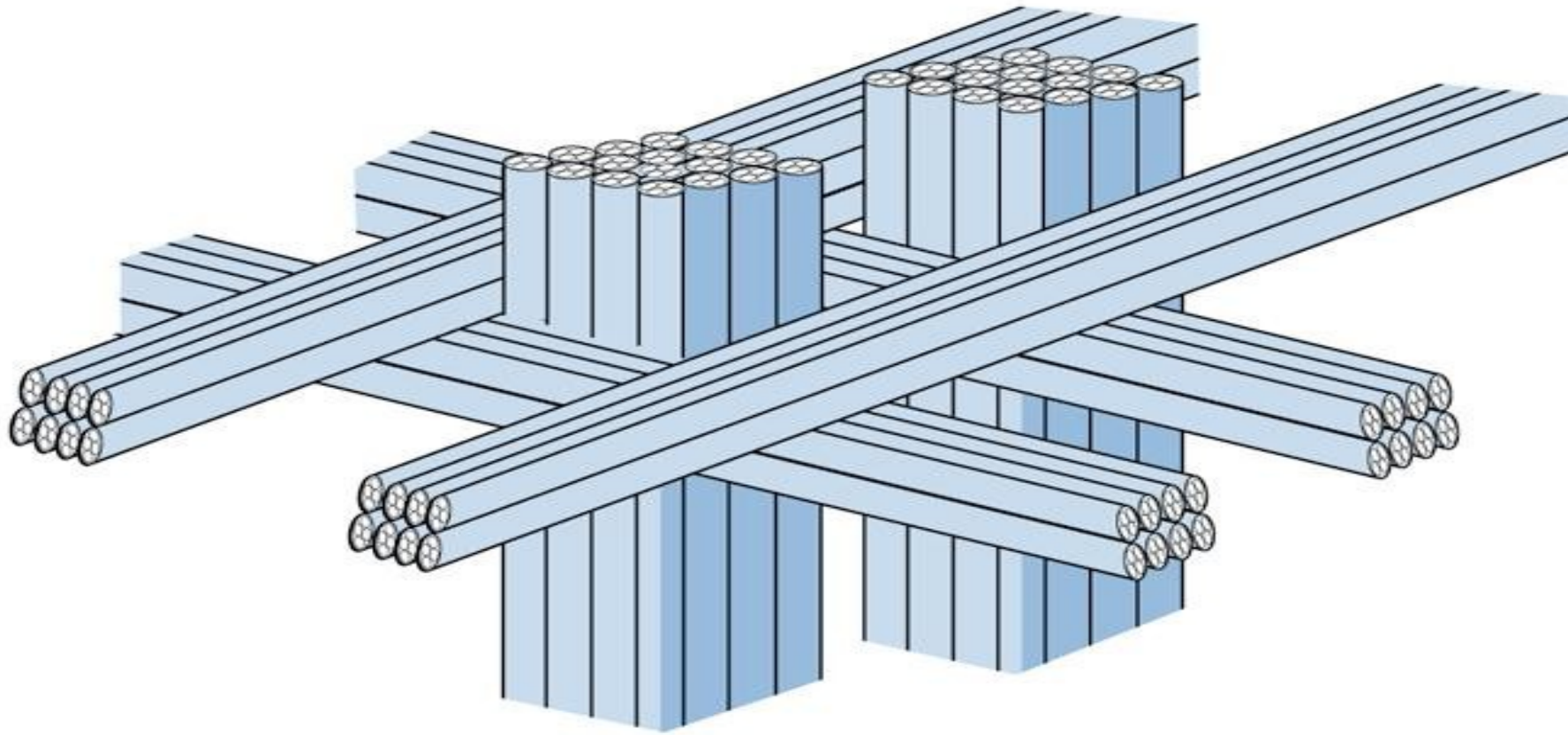


Effect of fiber orientation on the tensile strength of E-glass fiber-reinforced epoxy composites.



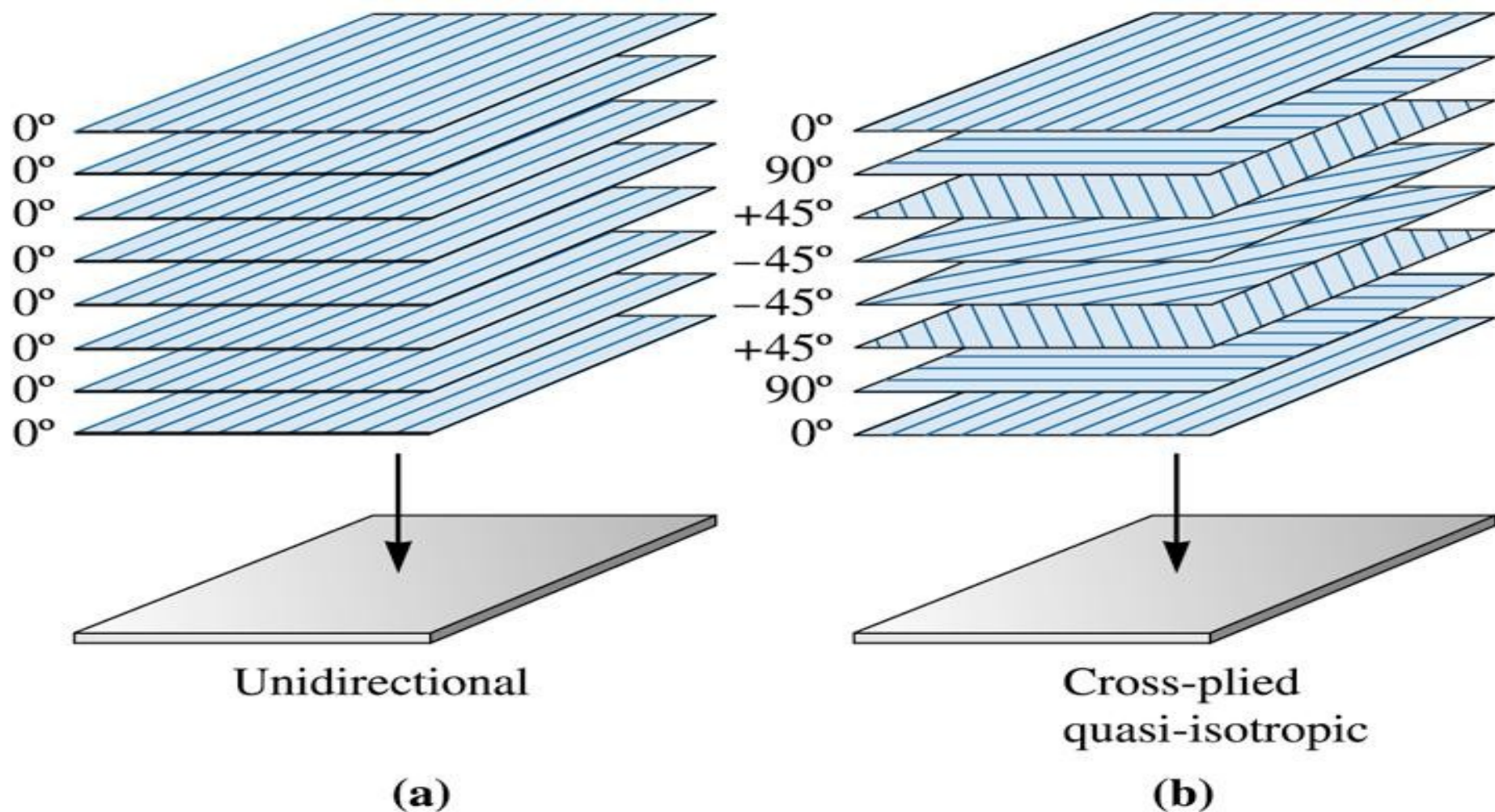
Size distribution of particles used as reinforcement





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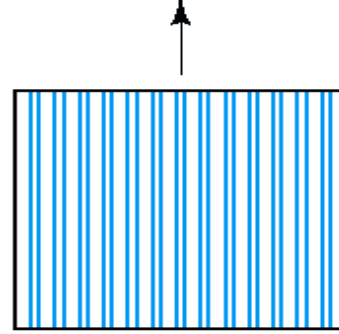
□ **A three-dimensional weave for fiber-reinforced composites.**



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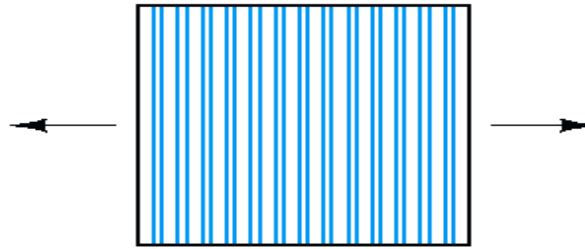
- (a) Tapes containing aligned fibers can be joined to produce a multi-layered different orientations to produce a quasi-isotropic composite. In this case, a $0^\circ/+45^\circ/90^\circ$ composite is formed.

Unidirectional composite



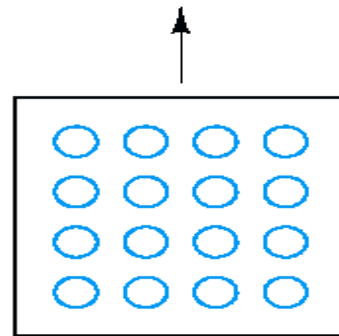
(a)

**Longitudinal
direction**



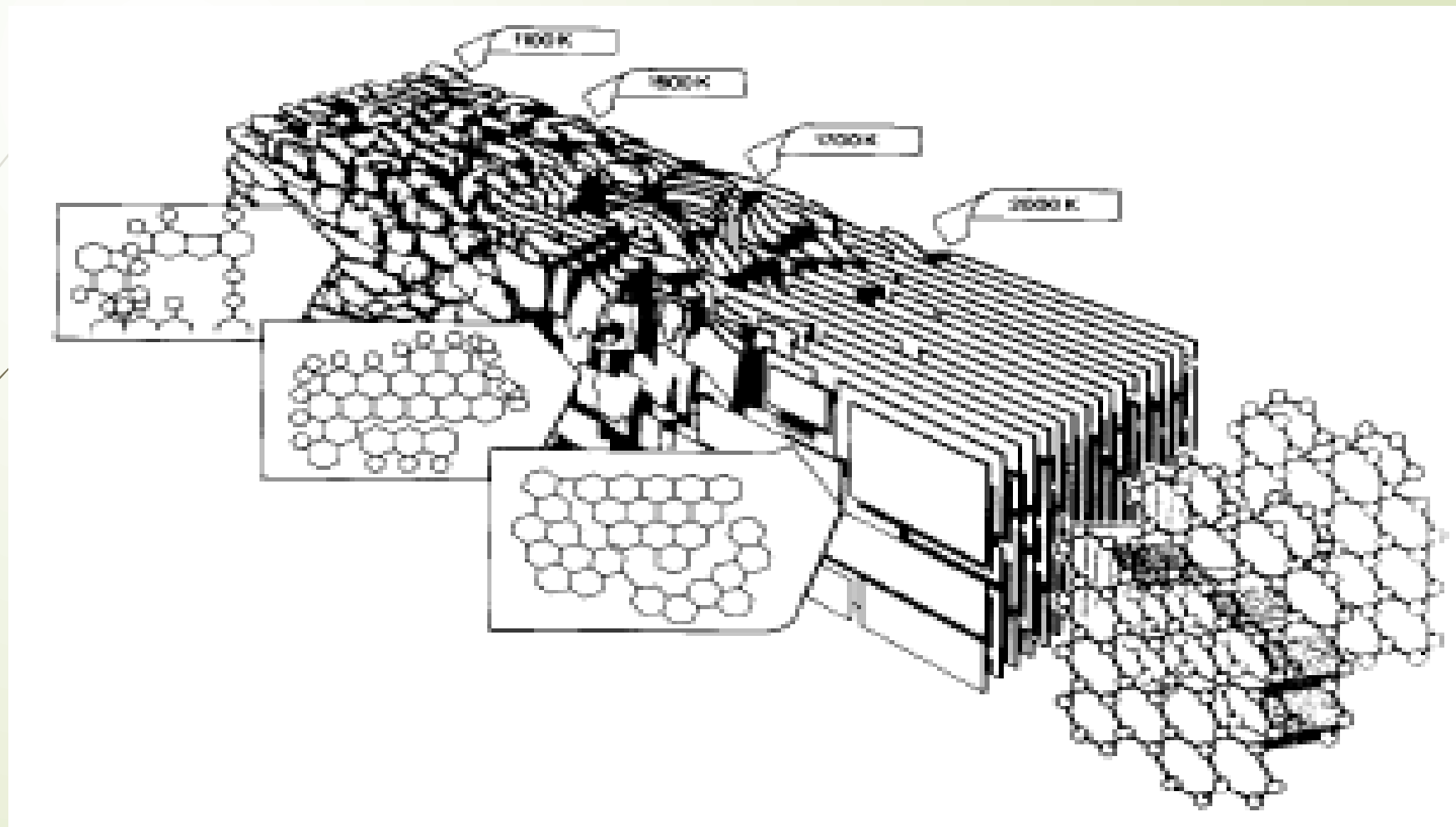
(b)

**Transverse
direction**

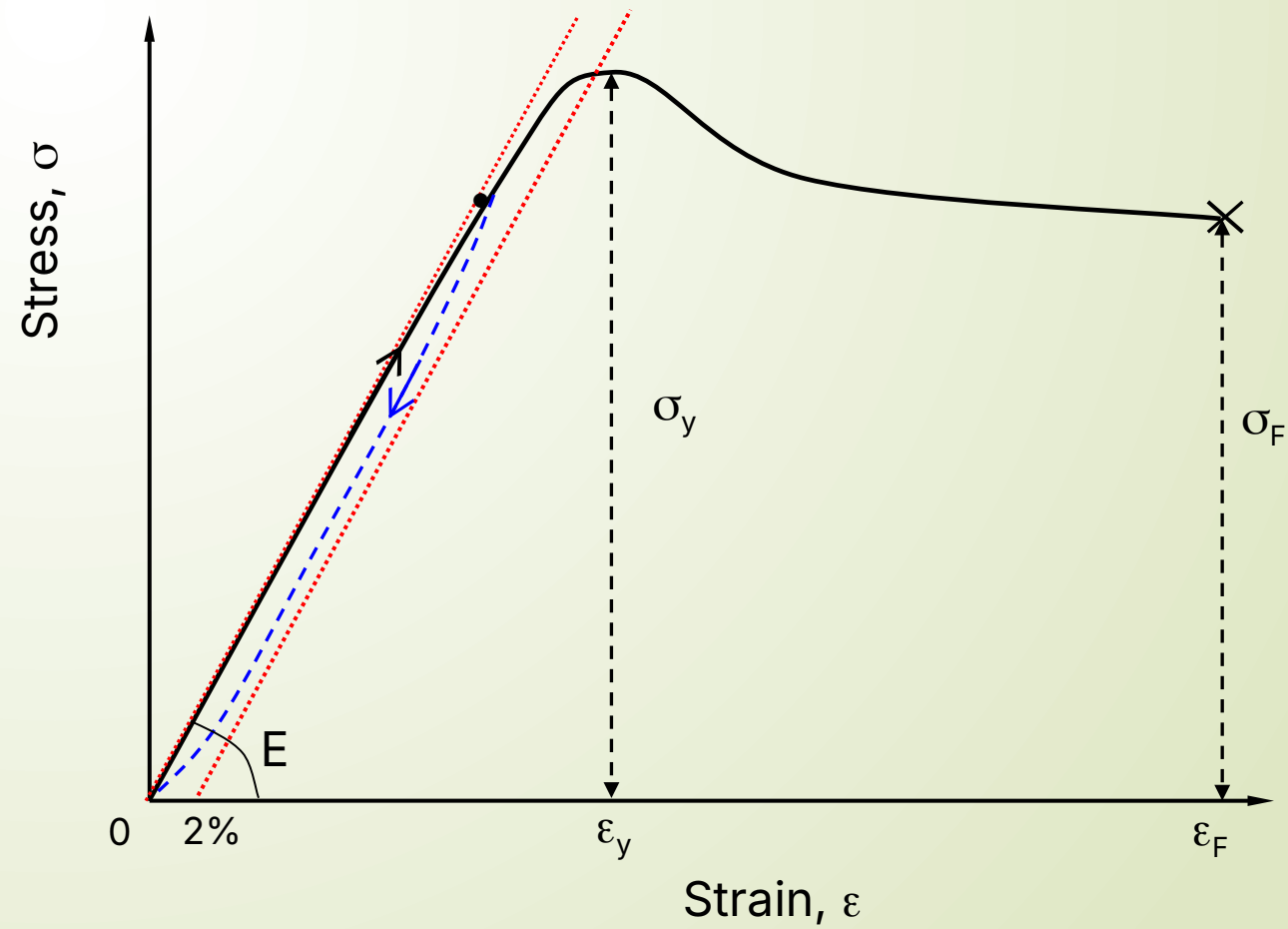


(c)

**Through-
thickness
direction**

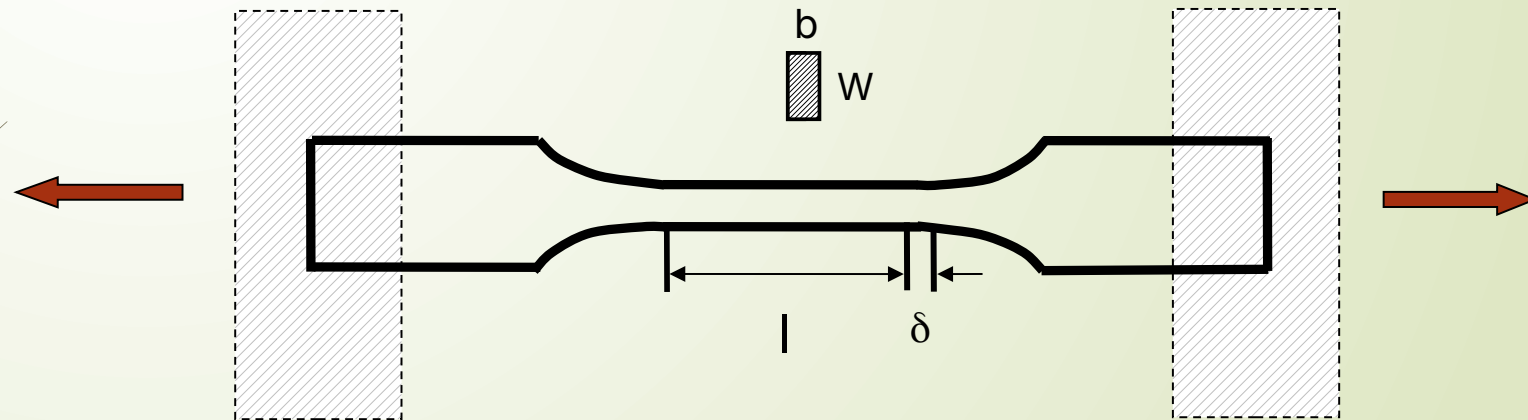


Definition of Deformation



Illustrations of Deformation

Tension:



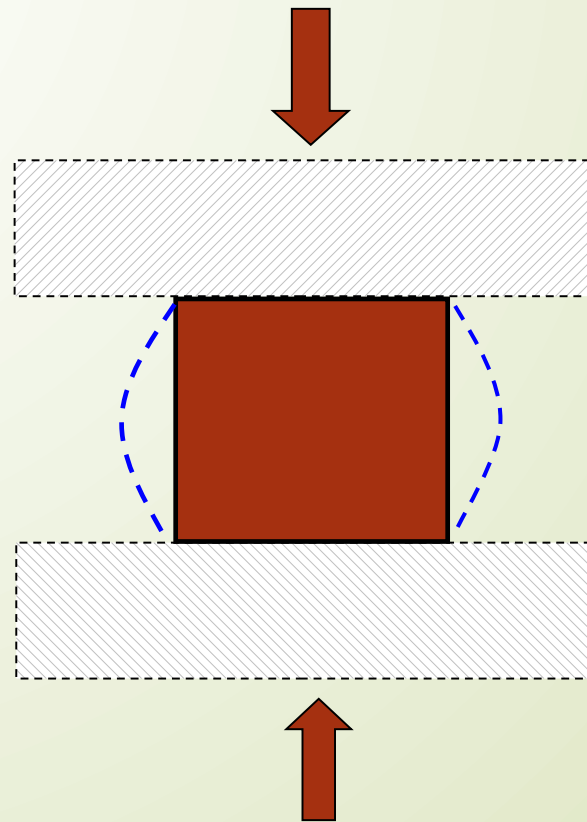
$$\epsilon = \delta / l$$

$$\sigma = F / bw$$

$$E = \sigma / \epsilon = (F / \delta) (l / bw)$$

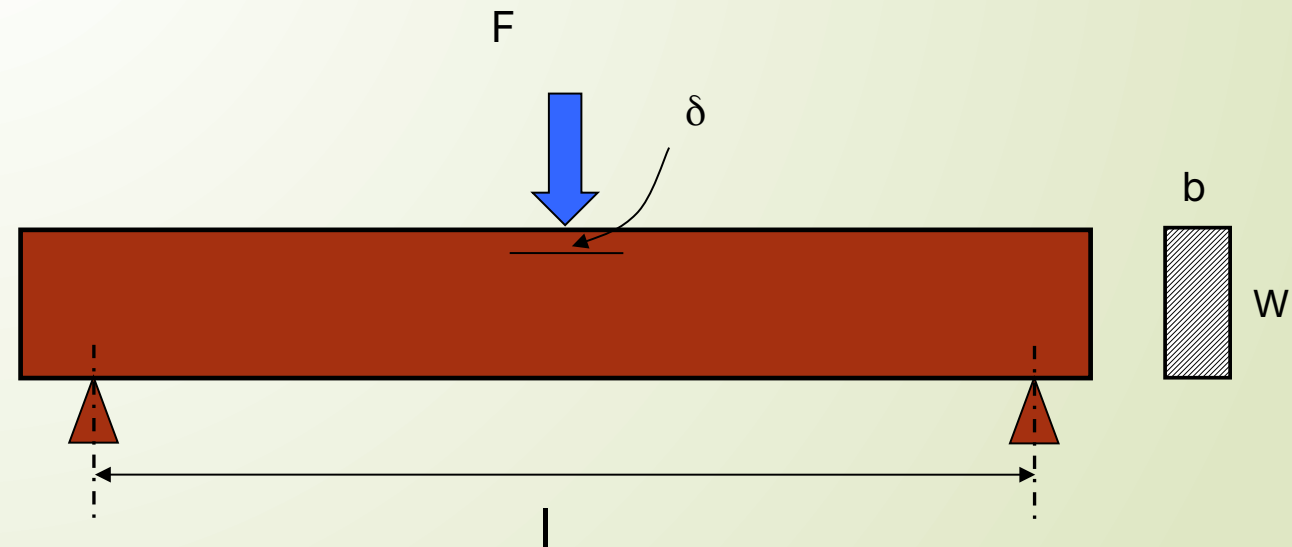
Illustrations of Deformation

Compression:



Illustrations of Deformation

Bending:



$$E = \sigma / \epsilon = (F / \delta) (l / bW) (l^2 / 4W^2)$$

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Thank you

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