Stronger glass products

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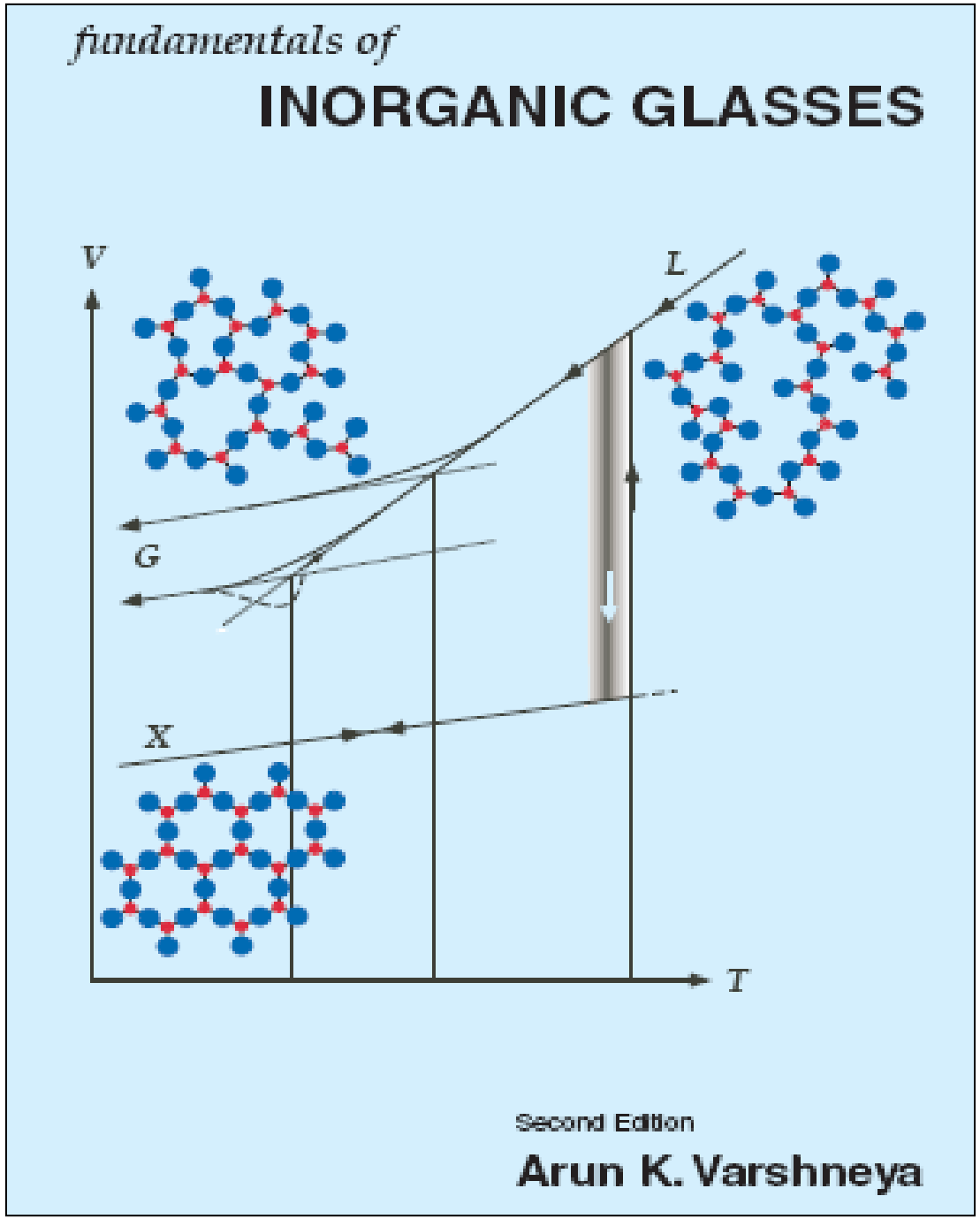
International Year of Glass



Name four glass products that have brought much comfort to human living

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How do you make a glass?

14%Na_2O-10%CaO-2%Al_2O_3-74%SiO_2

Typical raw materials:

Commonly occurring minerals of the Earth.

Na_2CO_3 = soda ash

$CaCO_3$ = Lime stone

$Al_2O_3.2SiO_2.2H_2O$ = Clay

SiO_2 = Sand

Melt at ~1450°C

Infinitely recyclable

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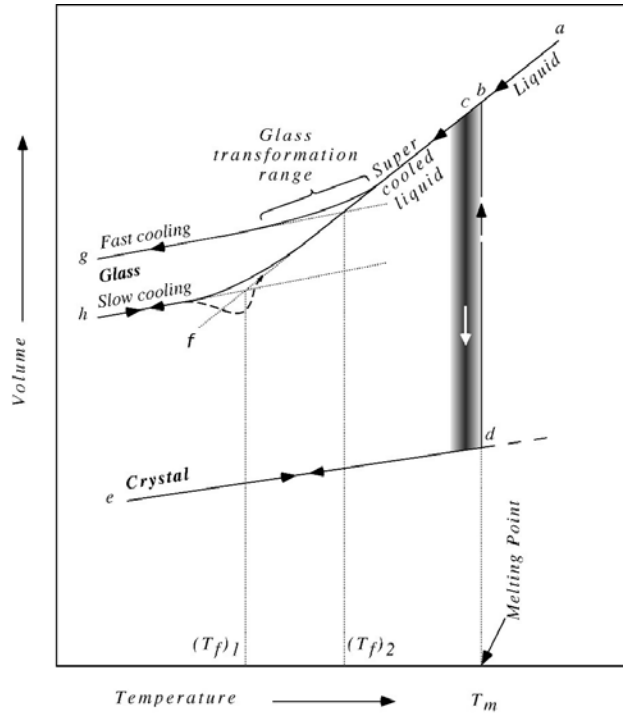

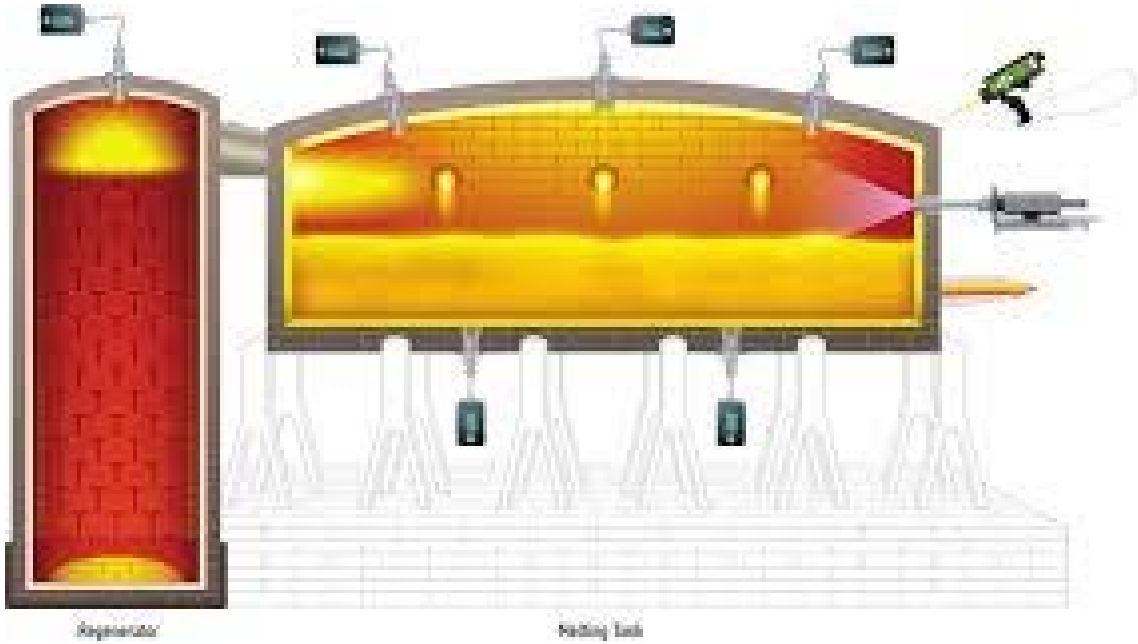

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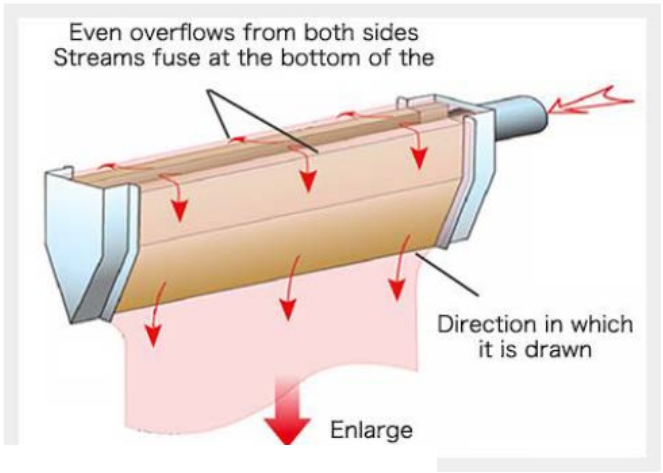
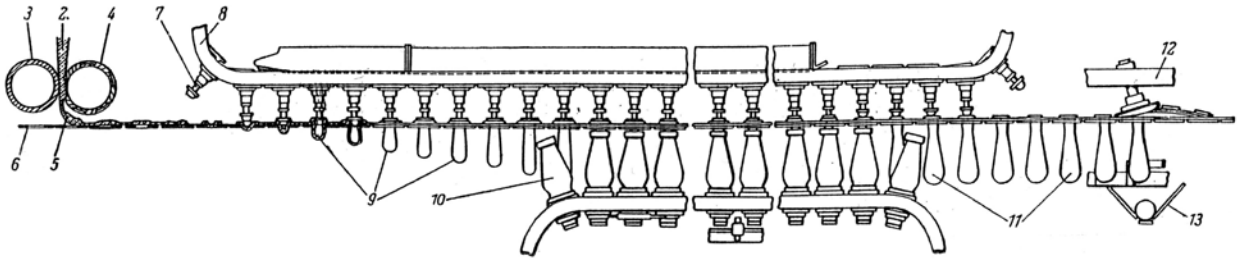
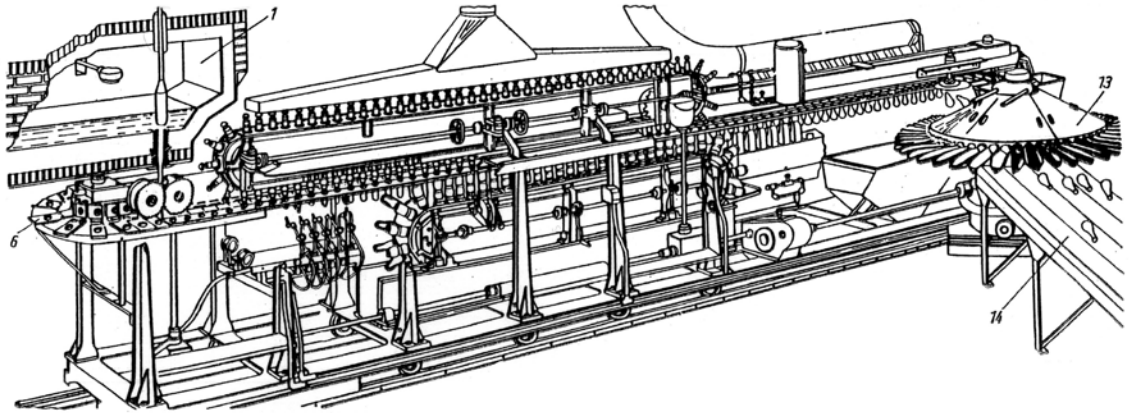
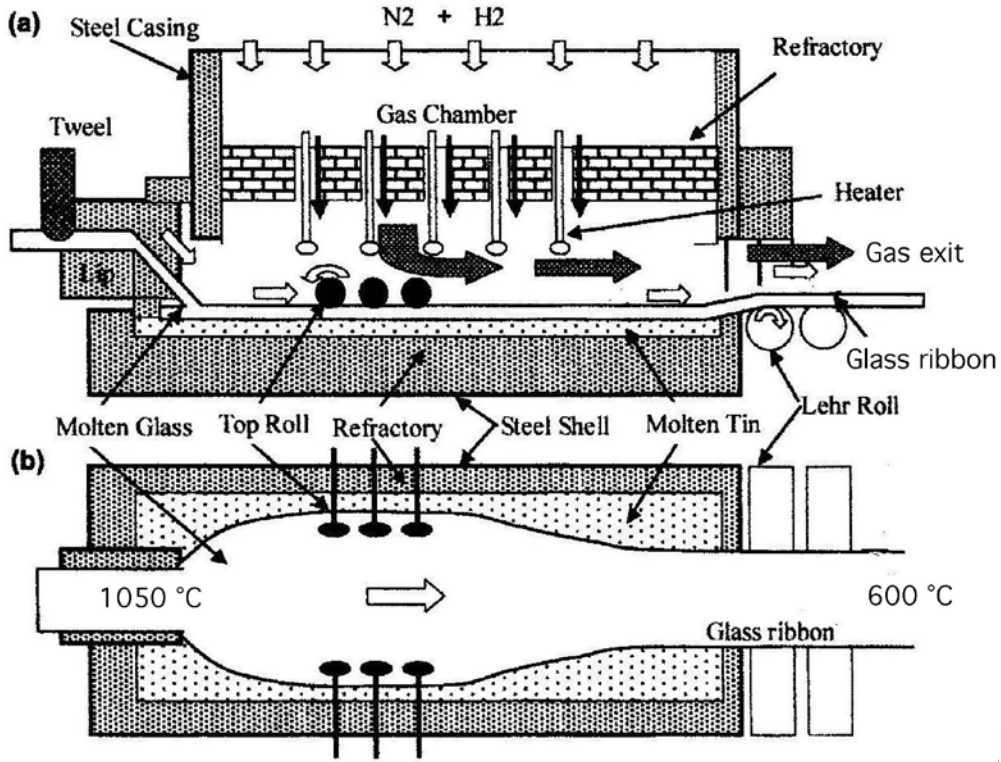




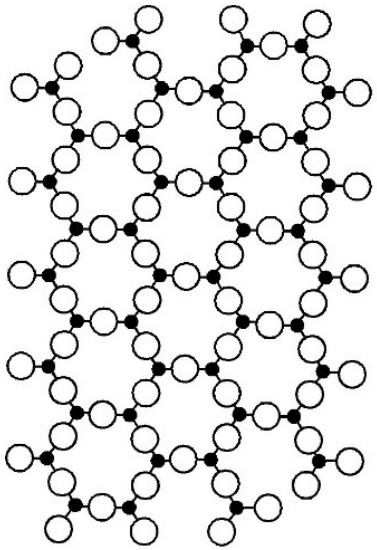


Construction of a Ribbon glass bulb machine of Corning Glass Works. Daily output more than 1 million bulbs.
1 glass furnace; *2* cord of viscous glass; *3* smooth roll; *4* profile roll; *5* rolled ribbon of glass, with impressed blobs; *6* conveyor belt made of perforated metal plates; *7* blowing heads; *8* carrier belt for *7*; *9* glass bulbs blown through the holes in the conveyor belt; *10* split molds carried on conveyor below *6* and surrounding bulbs *9*; *11* finished glass bulb; *12* separator; *13* take-off device; *14* conveyor for bulbs to annealing oven

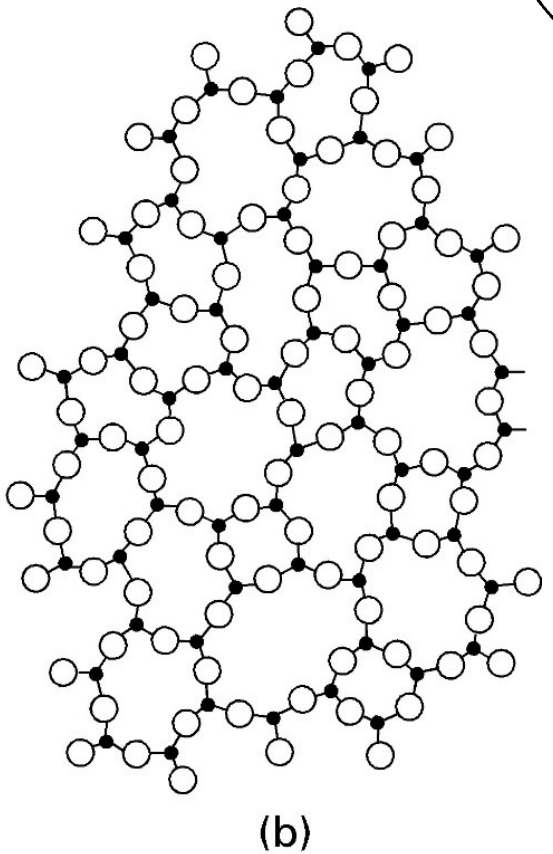


Solid Materials

Metals
Polymers
Ceramics
Glasses
Paper



(a)



(b)

Classification by atomic order

Crystalline solids
Non-Crystalline solids (amorphous, glasses)

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What is force *F*?

F = a push or a pull that would bring a change in the motion of a mass *m*

F = Applied load

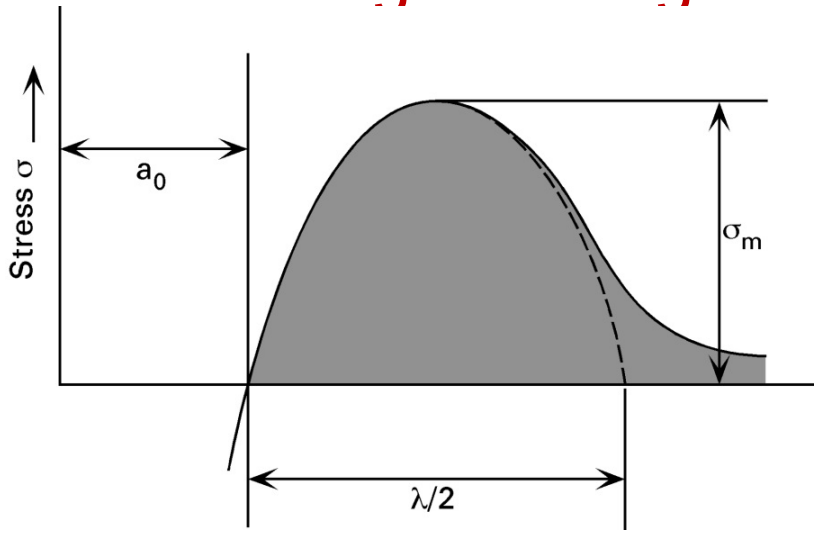
If you place 1 kg mass on the body, $F = mg$

What is stress σ? σ = Applied force/area of application

When you apply a stress on a body, what happens?

$\sigma = E\,\varepsilon$; *E* = modulus of elasticity;

ε = strain = change in length /original length



Theoretical strength

Distance between two neighboring atoms

What is a ductile or a brittle material?

Ductile material such as aluminum wire, copper plate.
Application of stress beyond an “elastic limit” causes them to permanently become longer, or permanently bend.

Dislocation motion in the atomic structure brings about “plasticity”.

Energy is spent. So you have to apply more and more energy to ultimately cause fracture in a metal.

Fracture = atoms are separating permanently

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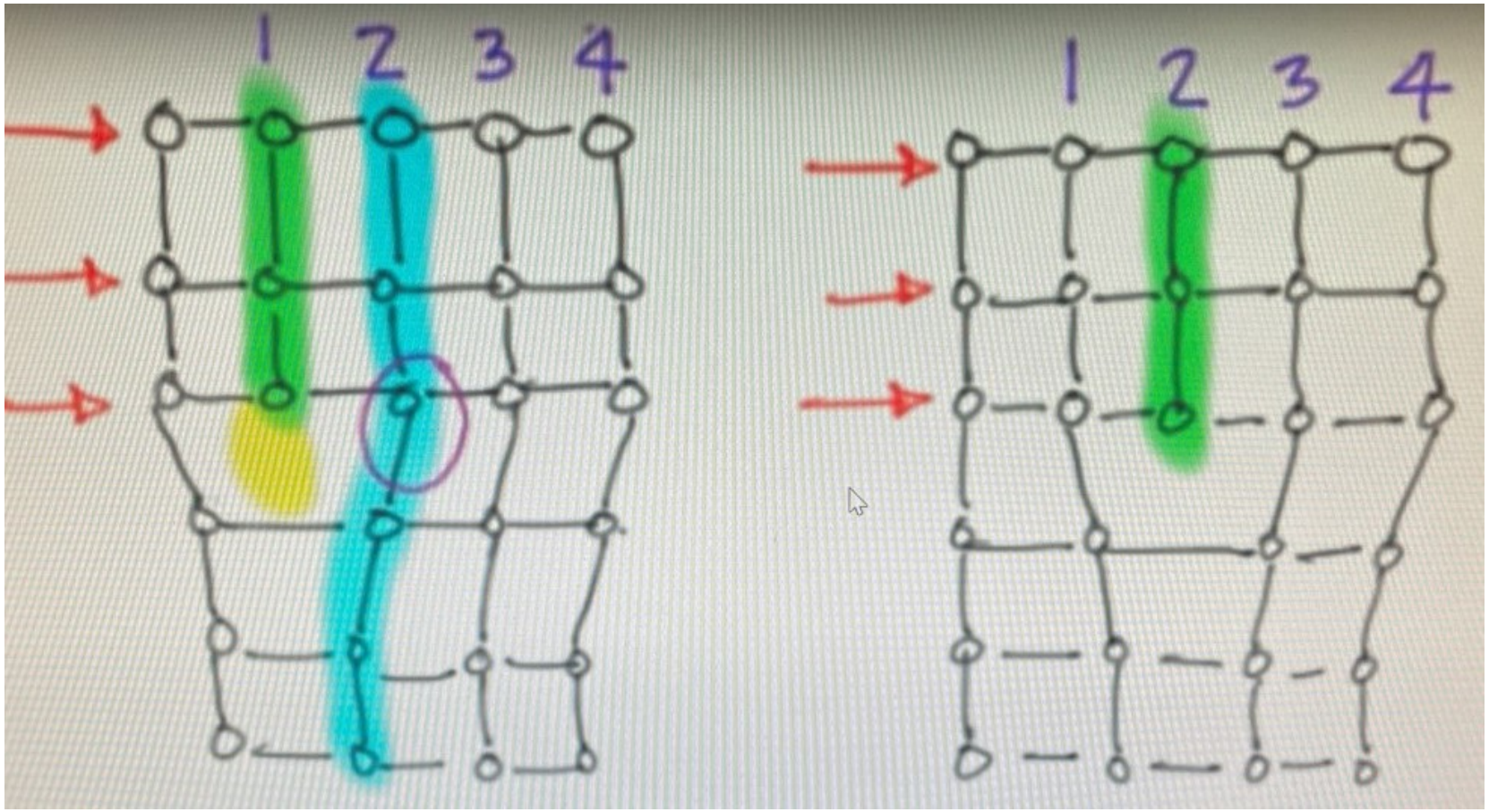
Dislocation motion in a crystal can lead to plastic deformation

Shear stress



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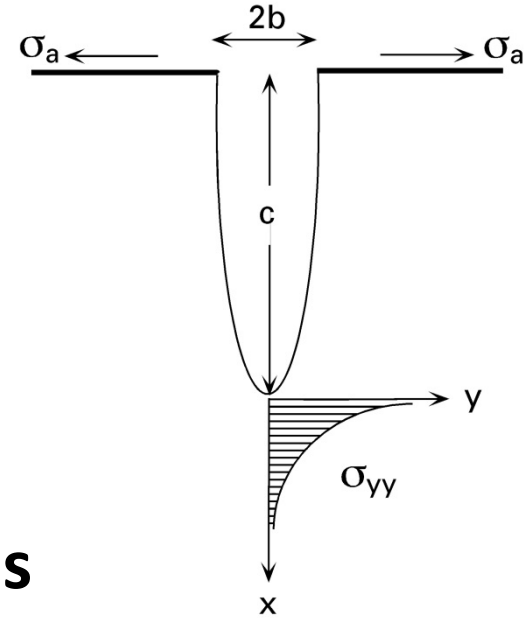
Theoretical strength of a glass around 35 Gpa
But glass products break at as little as 20 MPa

In a glass structure, there is no such thing as a dislocation. Thus stress continues to build.

Atomic sized surface flaws act as stress intensifiers. Fracture starts at the tip of the flaw when the stress exceeds the strength of the atomic bond.



Weakest link argument

Severity of a flaw is described in terms of length/radius of curvature at the tip.
Even a 5 micron sized flaw can reduce the practical strength by a factor of 400-600

"Griffith flaws"

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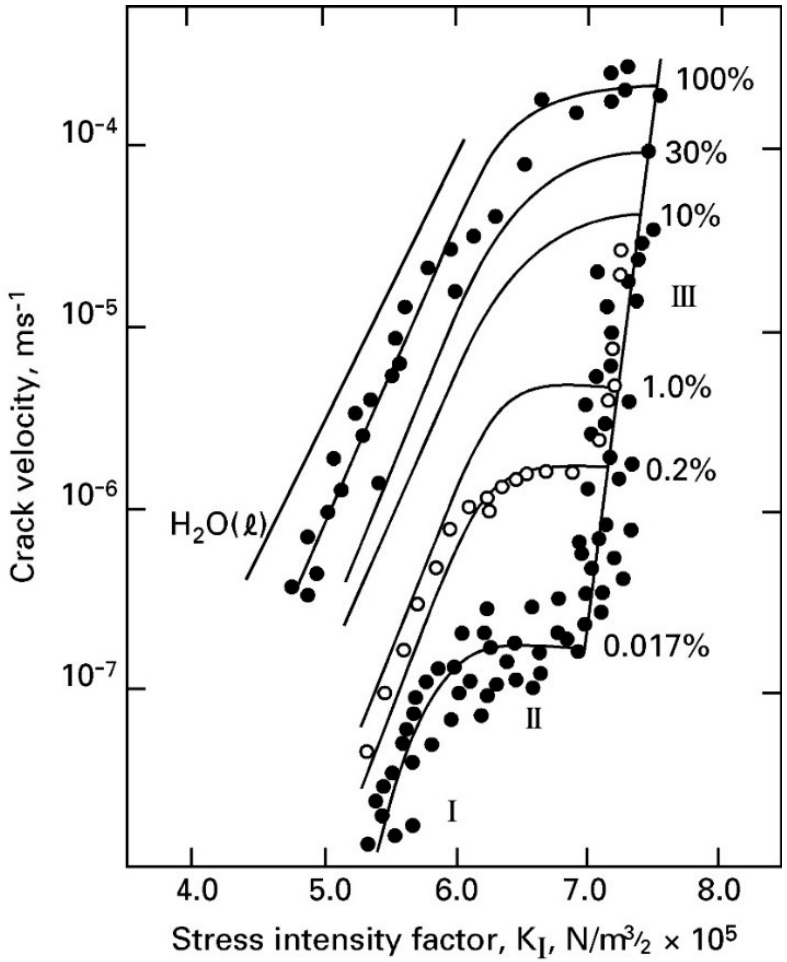
Effect of water on glass strength



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Glass only breaks in tension, usually from a surface flaw

How to strengthen glass products?

(1)Remove flaws (or use surface barrier coatings)
(2)Insert a large compression in the surface. Applied stress must exceed the compression first.

Most common commercial techniques:
Thermal tempering
Chemical strengthening
Lamination

There is no such thing as “unbreakable glass”

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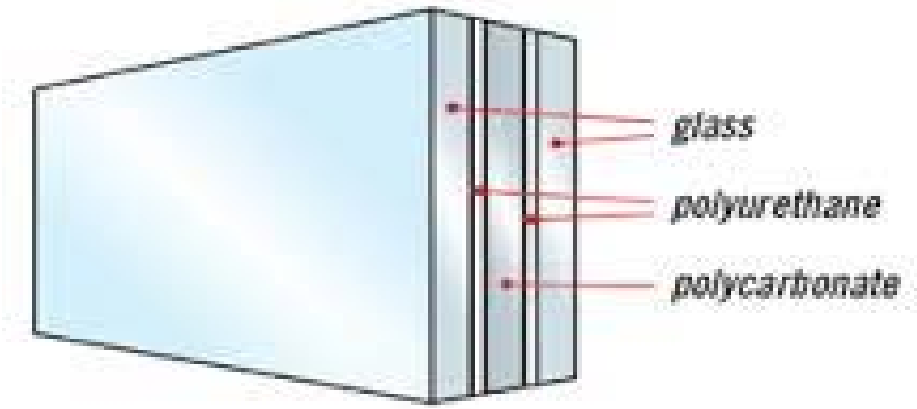
Lamination



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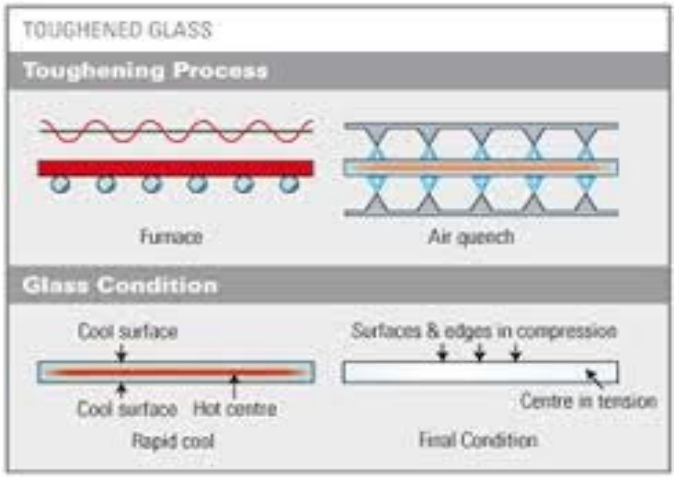
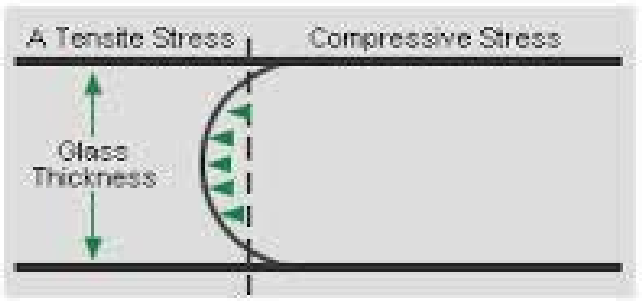
Thermal tempering



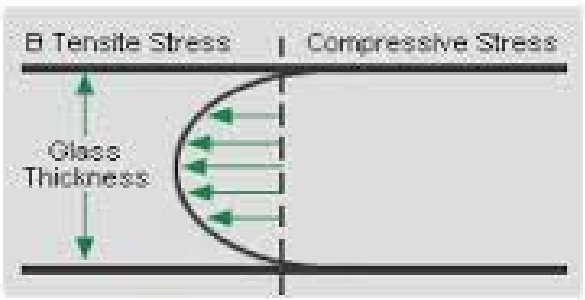
Kind “HS” Heat strengthened
5,000-7,500 psi surface compression

Kind “FT” Fully tempered
14,500 psi surface compression

Kind HS has much less optical distortion



Heat Strengthened Glass



Tempered Glass

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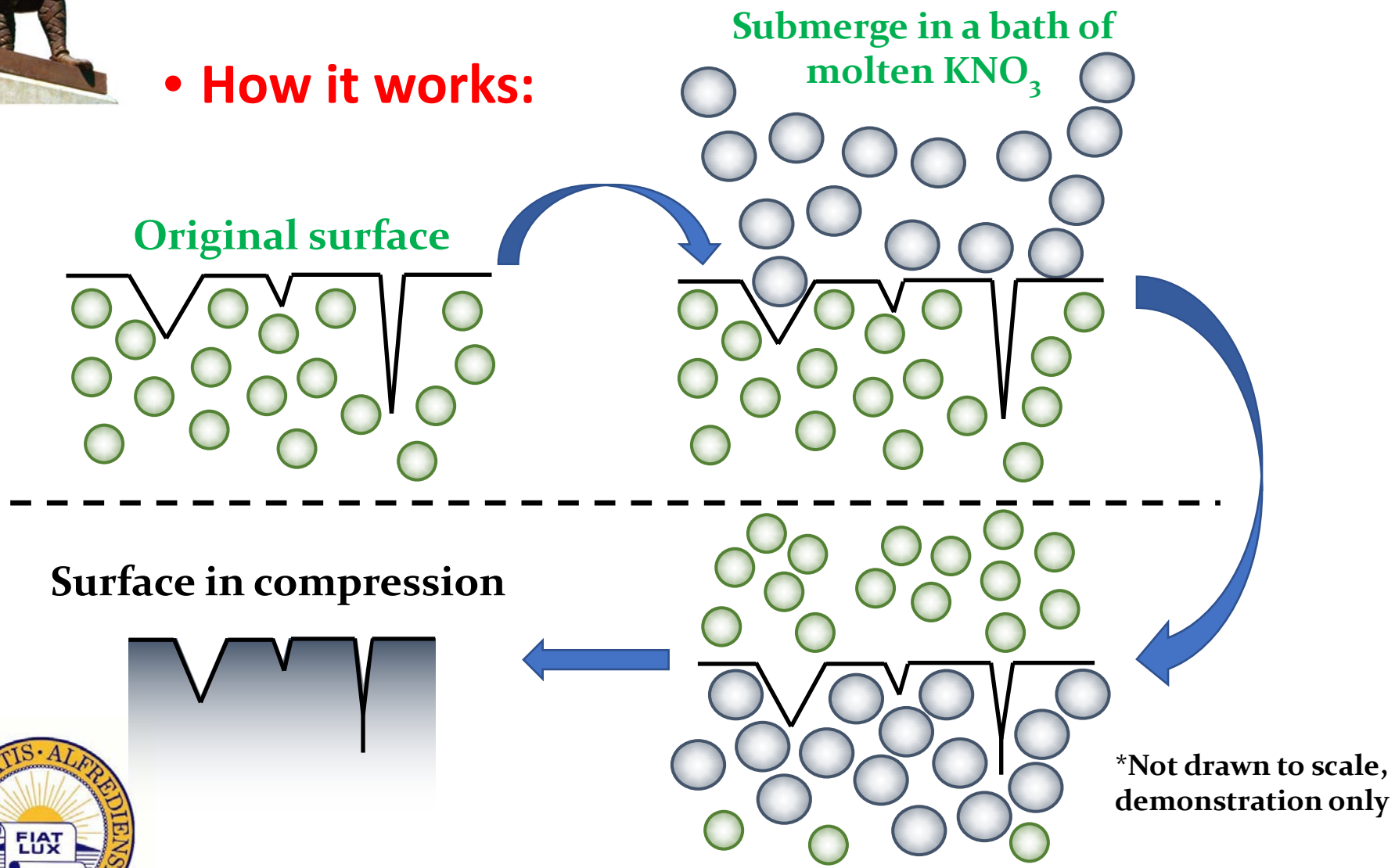
Chemical Strengthening

- **How it works:**



Ion Size

Na^+ (0.95 Å)

K^+ (1.33 Å)

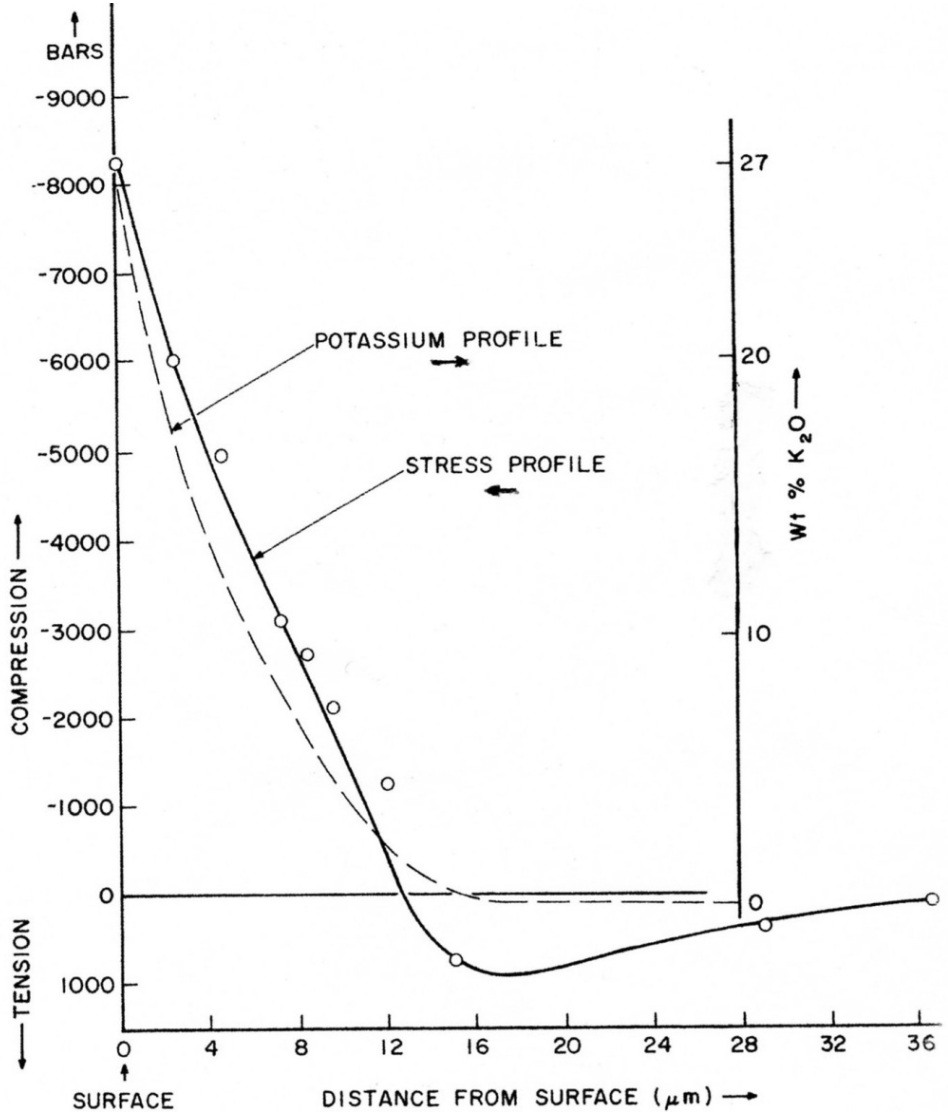
Concentration of invading ion and stress vs depth

IMPORTANT PARAMETERS:

(1) MAGNITUDE OF SURFACE COMPRESSION

(2) CASE-DEPTH

- ***Basis of ASTM C-1422***



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INTERNATIONAL YEAR OF GLASS 2022

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Work by Professor L. David Pye

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Third Edition

Fundamentals of Inorganic Glasses

Arun K. Varshneya and John C. Mauro

A comprehensive textbook in the field of glass science and engineering.

The third edition of *Fundamentals of Inorganic Glasses* has been updated with the most recent advances in glass physics and chemistry, as well as discussions of new groundbreaking applications of glassy materials. This book is suitable for upper level glass science courses, as well as for professional glass scientists and engineers. *Fundamentals of Inorganic Glasses* is the definitive reference for the field of glass science and engineering, offering comprehensive coverage of the composition, structure, and properties of inorganic glasses.

Key Features

- Clearly develops fundamental concepts and the basics of glass physics and chemistry and glass engineering technology.
- Provides an extensive discussion of the composition, structure, and properties of inorganic glasses.
- Features a discussion of the emerging applications of glass, including applications in energy, environment, pharmaceuticals, and more.
- Concludes chapters with summaries and problem sets to facilitate self-study.

Dr. Arun K. Varshneya is Professor Emeritus of Glass Science and Engineering at Alfred University. Prior to joining the faculty at Alfred's New York State College of Ceramics in 1982, he worked as a senior scientist for Ford and General Electric Lighting Business Group. Arun is currently the president of Saxon Glass Technologies Inc. which specializes in strengthening glass for various industries. He is the invited author of the "Industrial Glass" entry in Encyclopedia Britannica and has more than 160 technical publications covering a broad range of topics in glass. Arun is a Distinguished Life Member of the American Ceramics Society, an Honorary Fellow of the Society of Glass Technology, and a recipient of the President's Award from the International Commission on Glass for lifetime achievements. Varshneya earned a BSc from Agra University in India, a BSc with Honors in glass technology from the University of Sheffield (UK), and MS and PhD in materials science, both from Case Western Reserve University in Cleveland, Ohio.

Dr. John C. Mauro is Professor of Materials Science and Engineering at The Pennsylvania State University. John earned a BS in Glass Engineering Science (2001), BA in Computer Science (2001), and PhD in Glass Science (2006), all from Alfred University. He joined Corning Incorporated in 1999 and served in multiple roles there, including Senior Research Manager of the Glass Research department. John is the inventor or coinventor of several new glass compositions for Corning, including Corning Gorilla® Glass products. John joined the faculty at Penn State in 2017 and is currently a world-recognized expert in fundamental and applied glass science, statistical mechanics, computational and condensed matter physics, thermodynamics, and the topology of disordered networks. John is the author of over 220 peer-reviewed publications and is Editor of the *Journal of the American Ceramic Society*. John is winner of numerous international awards and is a Fellow of the American Ceramic Society.

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Fundamentals of Inorganic Glasses

Varshneya

Mauro

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where science, technology and experience meet….

Kajal Varshneya, Chief Operating Officer

Chemically strengthened Type I borosilicate glass cartridge is housed in each and every EpiPen and Amneal autoinjector to reliably deliver epinephrine to avoid anaphylaxis shock in the event of life-threatening severe allergic reaction to peanuts, bee-stings and shell foods.

Prior to strengthening, the glass fracture rate during administration was ~10%. Glass chemical strengthening has reduced this probability to near zero.

Since 1996, nearly 0.5 billion strengthened glass cartridges have been supplied resulting in helping to save thousands of human lives each year.

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The American Ceramic Society
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celebrates

INTERNATIONAL YEAR OF GLASS 2022

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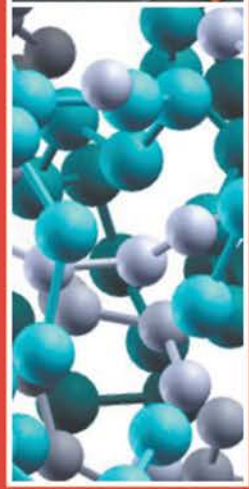

The American Ceramic Society

INTERNATIONAL YEAR OF GLASS 2022

International Year of Glass

Commemorative edition

NATIONAL DAY OF GLASS

A celebration following the United Nations' proclamation of 2022 as the International Year of Glass for the most transformative material that has done so much to enhance comforts of human living over the several millennia, for the pioneering spirit of people who contributed towards it and for continuing efforts towards sustainability of generations to come. Convened by The American Ceramic Society, the conference featured scientific, engineering, educational, artistic, and regulatory presentations by representatives from leading glass-themed organizations in North America.

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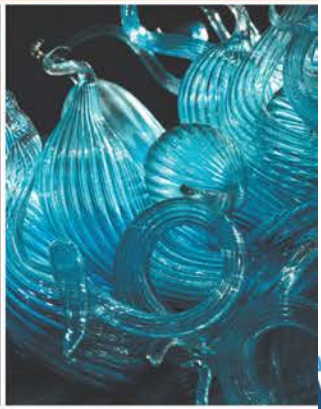
NATIONAL DAY OF GLASS

NATIONAL DAY OF GLASS

April 5-7, 2022 | Washington DC



Arun K. Varshneya • Manoj K. Choudhary • L. David Pye

Besides teaching and research in glass, there were two items I introduced as professor at Alfred University

The Faculty of Engineering will accept at least two credits in Performing Arts

All engineering students will have a “capstone” course involving business basics and team participation

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The Take-Away

Glass is beautiful

Many glass products have made our living comfortable

Glass education may be challenging but quite exciting

Glass profession is extremely satisfying. Life can be fun!

Be a volunteer in professional societies

We can all work together and use glass to make our precious planet sustainable for generations to come

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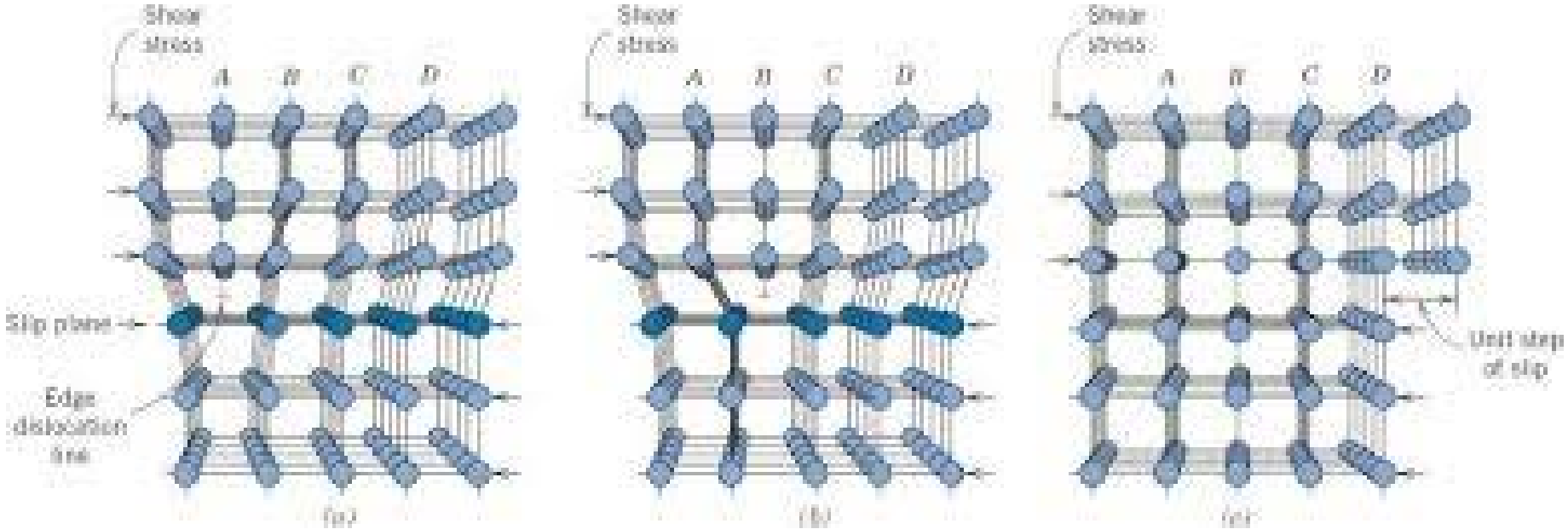
Shear stress
A
B
C
D
Slip plane
Edge dislocation line
(a)
Shear stress
A
B
C
D
(b)
Shear stress
A
B
C
D
Unit step of slip
(c)