
How do giant molecules wiggle?

Ashish Lele

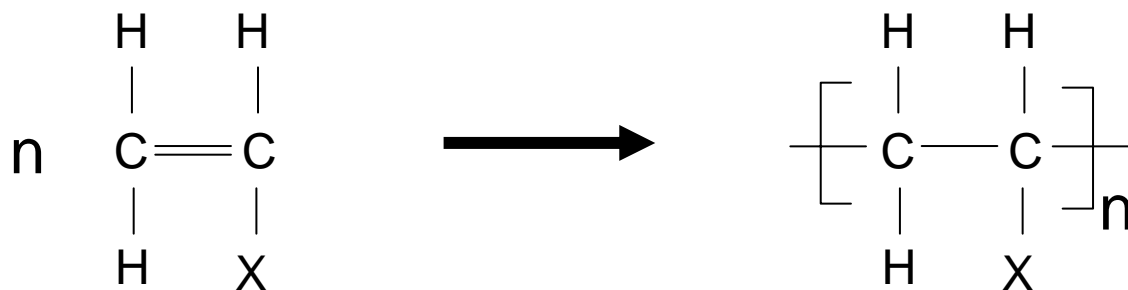
National Chemical Laboratory

Acknowledgement: Chirag, Omkar, NCL Academy

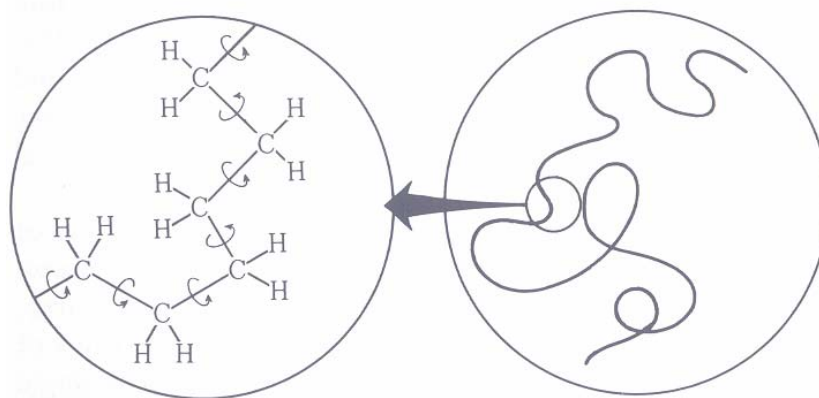
Contents

- Giant molecules and their applications
 - Unusual flow behaviour
 - Solids, liquids and....
 - Wiggling motions
-

Giant molecules



**Polymers OR
Macromolecules**

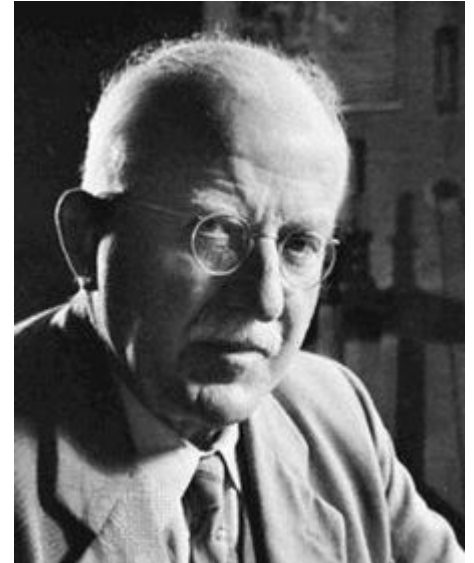


Giant molecules

Molecule	Molecular weight (g/mol)	Molecular size (Å)
H ₂	2	1.5
O ₂	32	3.0
CO ₂	44	3.3
Ethylene	28	1.7
Benzene	78	2.8
Fullerene C ₆₀	720	10
Polyethylene	50,000 – 5,000,000	100
Silk	400,000	100
DNA	>10 ⁶	7300

Long chains?

- Proposed the concept of polymers in 1920.
- Colloidal chemists rejected the idea.
- Awarded Nobel Prize in Chemistry in 1953.
- Rightfully called the father of polymer chemistry.



Hermann Staudinger
1881-1965

Can we live without them ?



Why are they so popular?

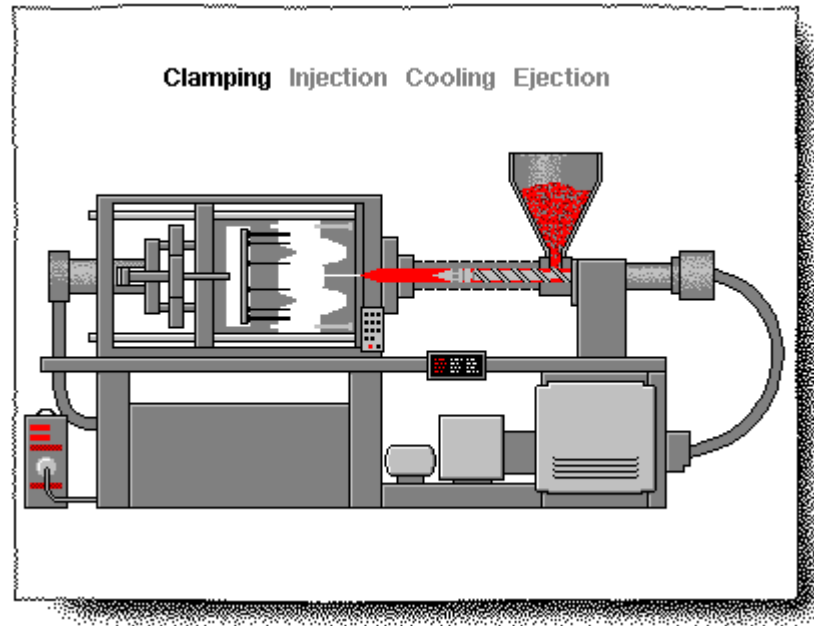
- Excellent properties
- Easy to shape into products
- Cheap
- Reusable
- Good service life
-

We consumed 7 million tons in 2008 !! (Mutha et al, 2006)

How are they shaped?



How are they shaped?



How are they shaped?

line for general purpose packaging films to seven layer blown film line for barrier films and technical grade films.

Multifoil co-extrusion blown film lines, incorporating latest technological advancements, are designed for absolute ease of operation and are the product of engineering excellence supported by stringent in-house quality standards and state-of-the-art manufacturing facilities coupled with unmatched after-sales services, excellent process back-up from a qualified team of professionals.

Multifoil co-extrusion blown film lines are available in host of configurations to suit various end product requirements with out-put ranging from 50 kg/hr to 1500 kg/hr and width up to 5000mm.







How are they shaped?



Vacuum Forming - Heating Material



Flow behaviour demos...

- Rod climbing 
 - Extrudate swell 
 - Melt fracture 
 - Filament stretching 
 - Dilatency and yield stress
-

Is this solid or liquid?



Solids (Elastic)

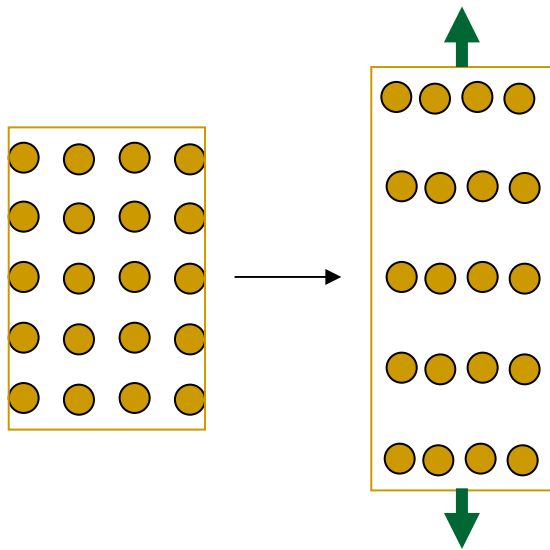
- Recovery (memory)
- Energy storage
- Hooke's law $F = -k x$



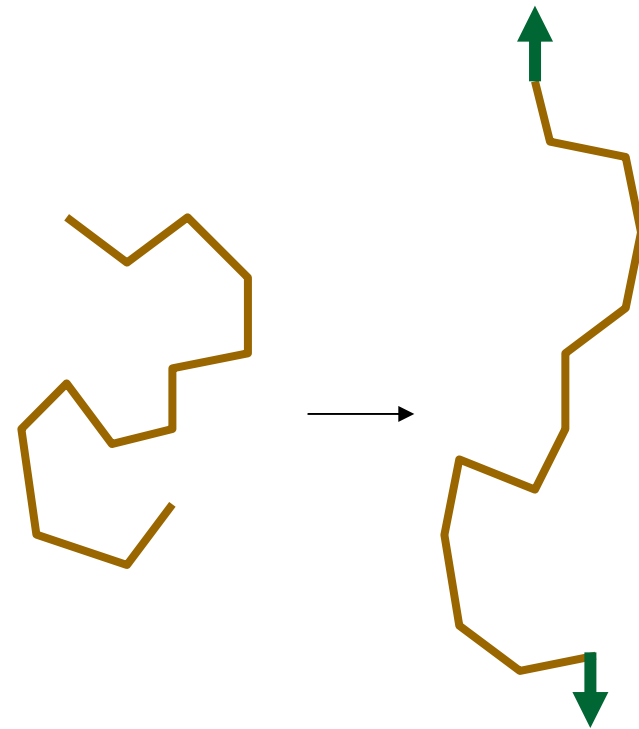
Robert Hooke
1635-1703

Homework: Can you render water elastic?

Molecular origin of elasticity

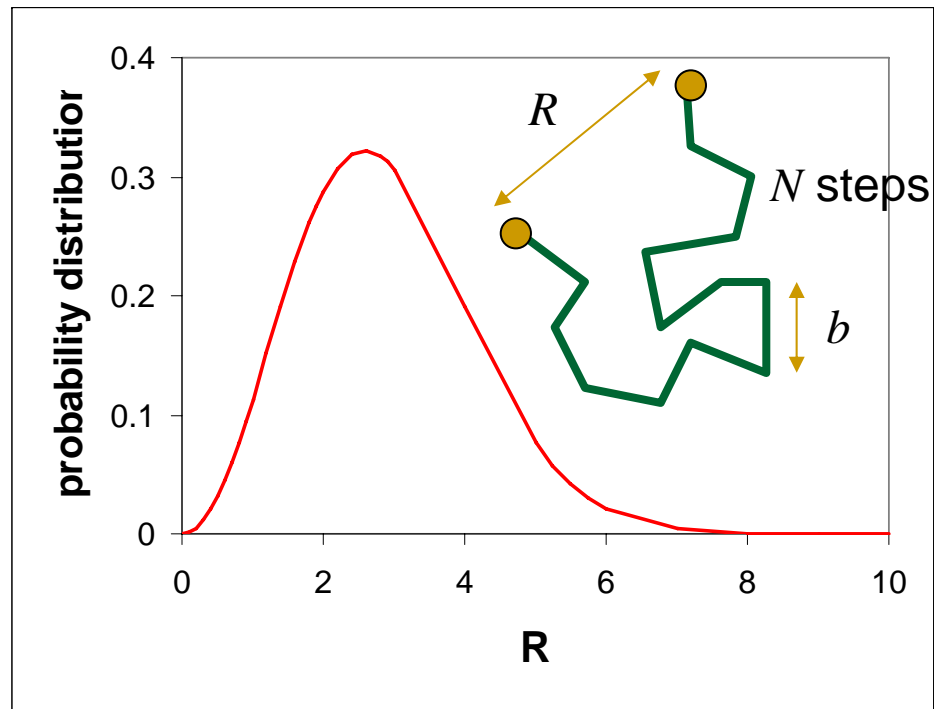


Bond stretching
Enthalpic



Bond rotation
Entropic

Molecular origin of elasticity

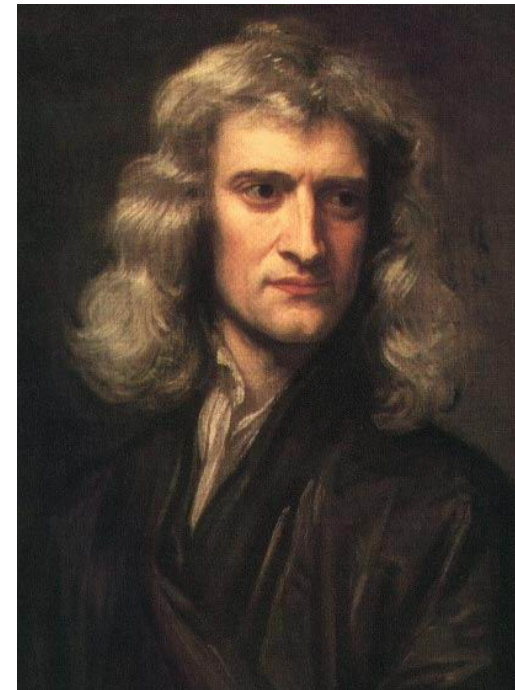


$$F = \frac{3k_B T}{Nb^2} R$$

Liquids (Viscous)

- Zero recovery (no memory)
- Energy dissipation

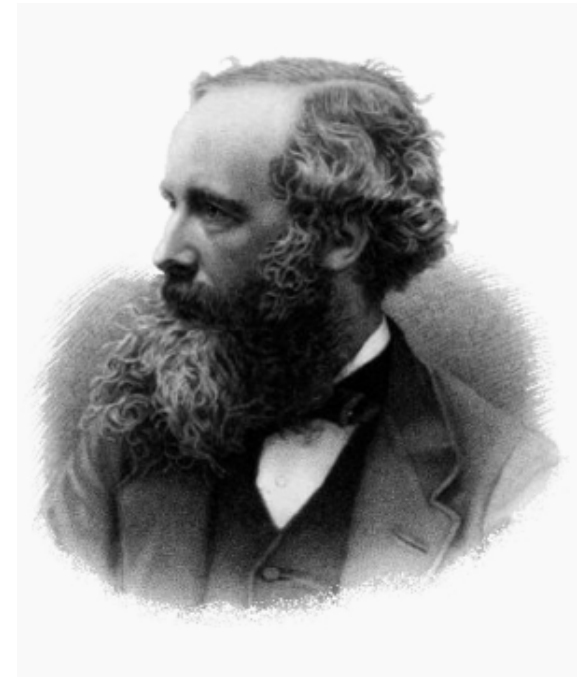
- Newton's law $F = -\eta A \frac{dv}{dy}$



Sir Isaac Newton
1642-1727

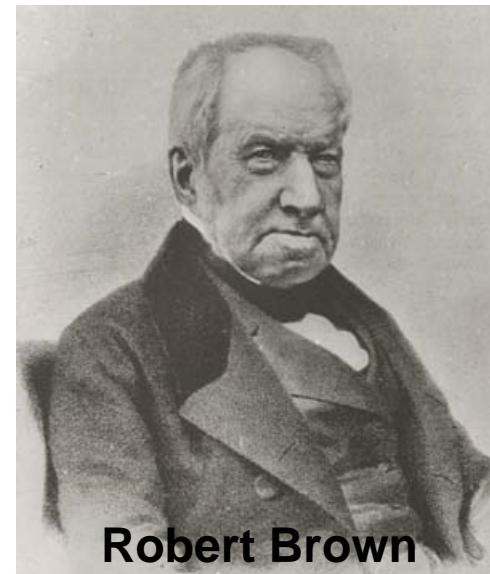
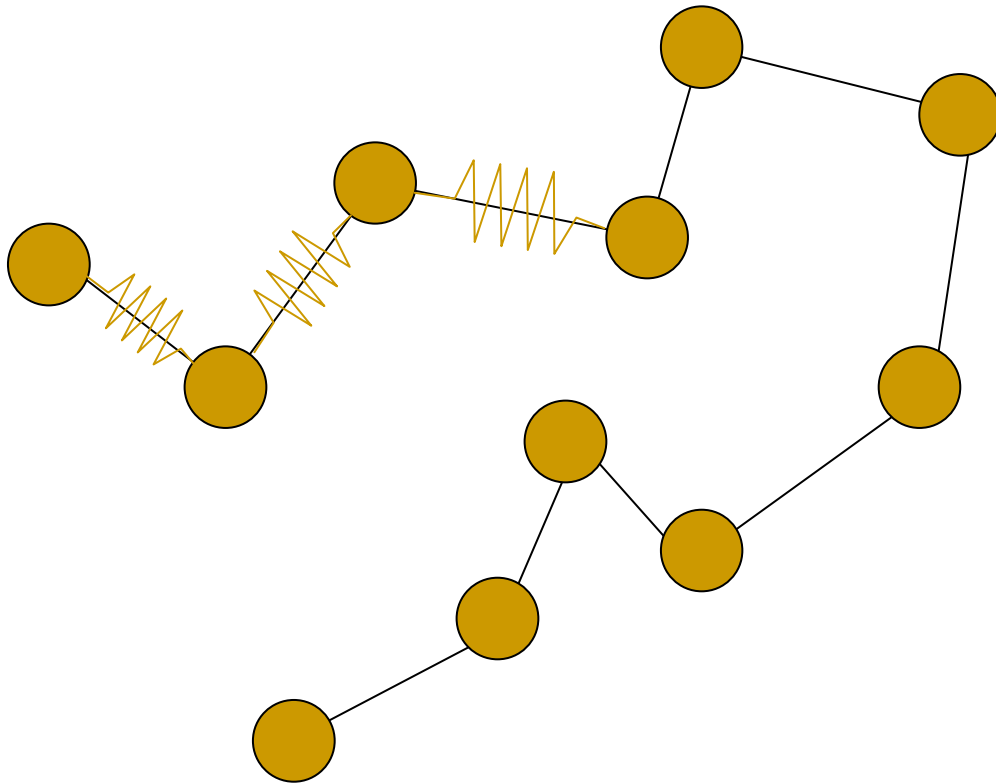
Viscoelasticity

James Clerk Maxwell
1831-1879



- Fading memory
- Short time elastic, long time viscous
- “*Mountains flow before the Lord*” $De = \frac{\lambda}{t_p}$

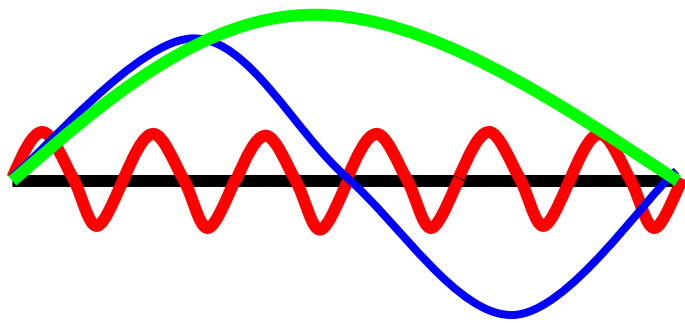
Wiggling in solutions



Robert Brown
1773-1858



Wiggling in solutions

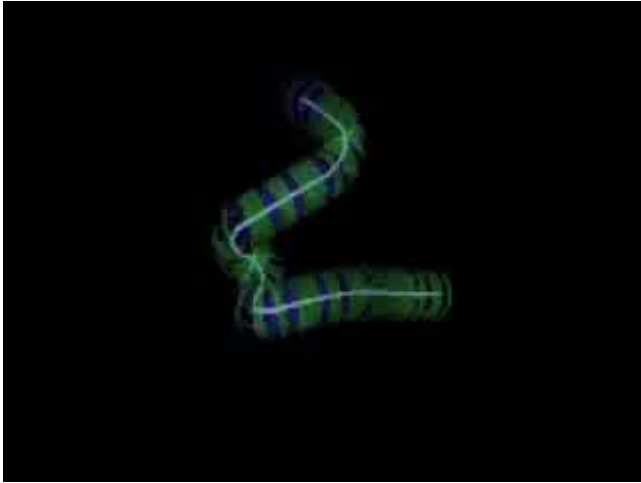


Plucked string of a guitar

Rouse, P.E. Jr., 1953

$$\lambda \approx \frac{b^2 \zeta}{k_B T} N^2$$

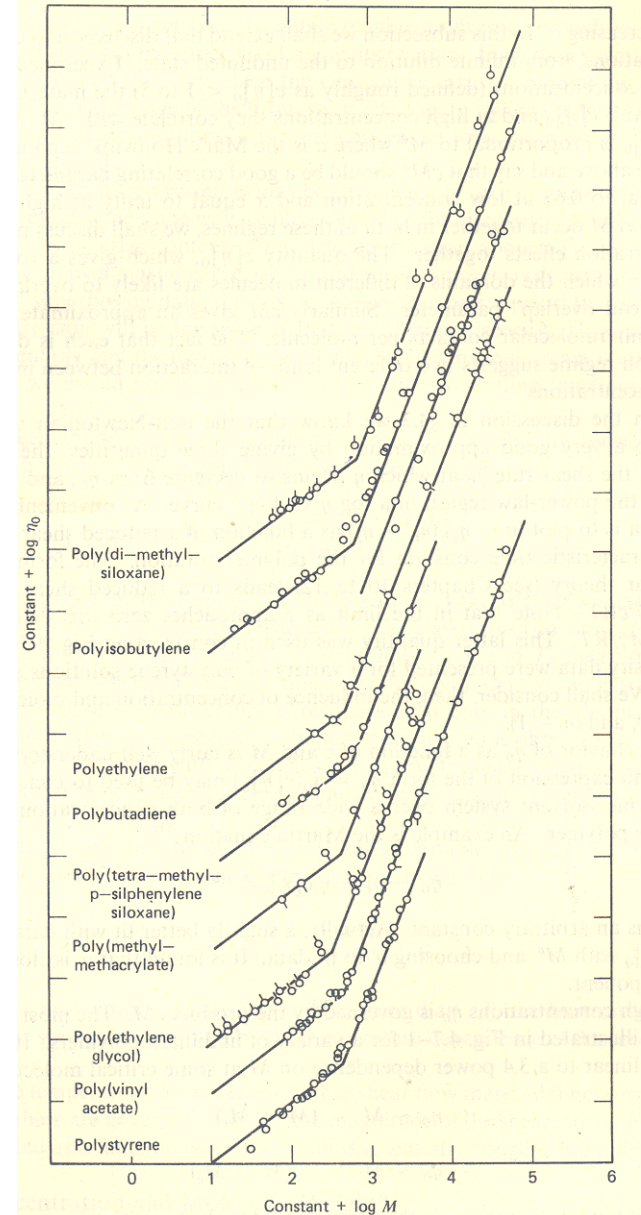
Wiggling in melts



Pierre de Gennes
1932-2007

$$D_c = \frac{k_B T}{N \zeta_{bead}}$$

$$\lambda = \frac{L^2}{D_c} \sim N^3$$

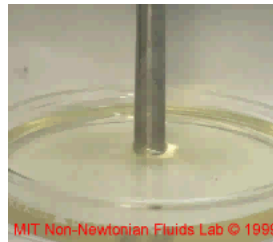


Why are wiggling motions important?

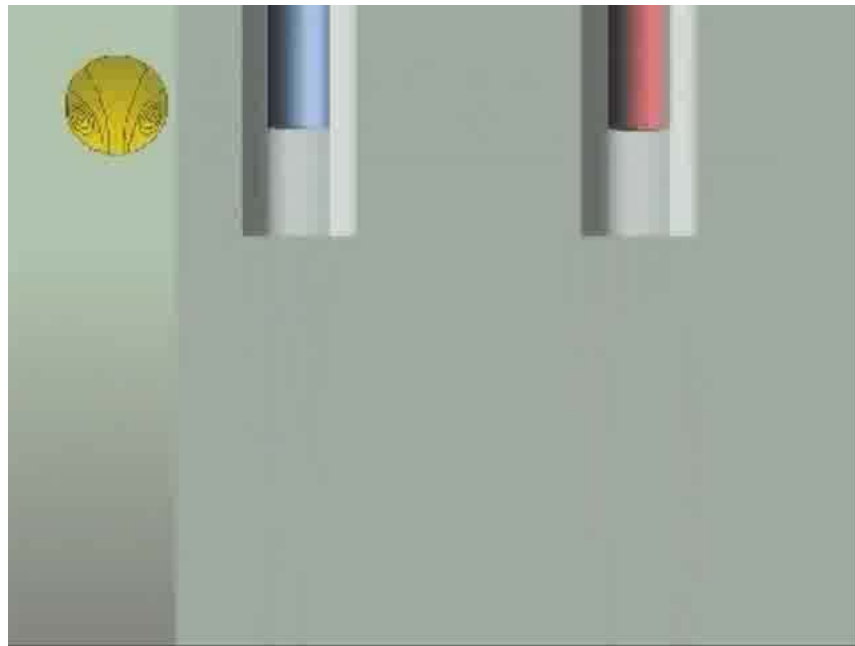
- Choosing the right polymer for an application.
 - Choosing the right equipment for a polymer.
 - Influence on solidification processes.
 - Biological processes.
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THANK YOU!

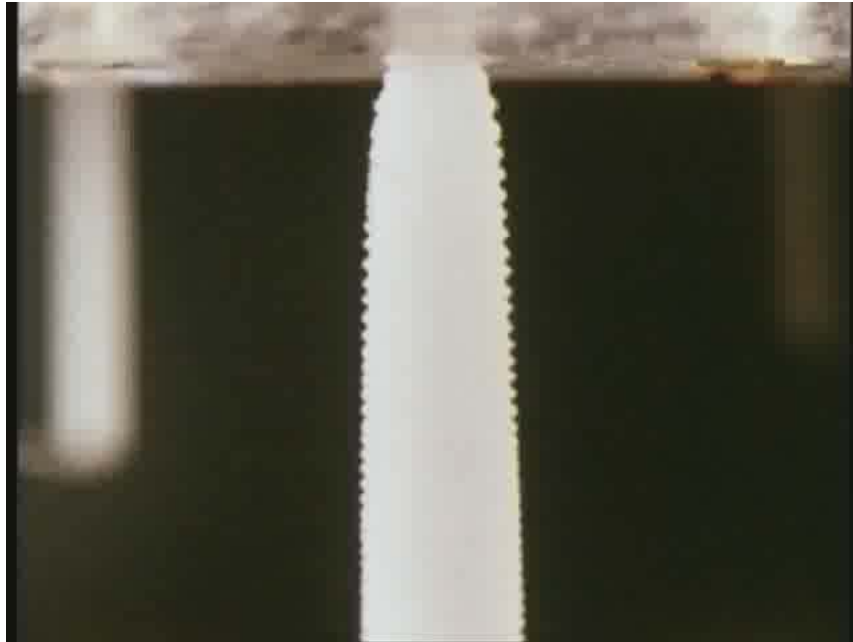
Rod climbing



Extrudate swell



Melt fracture



Filament stretching

