How do giant molecules wiggle?

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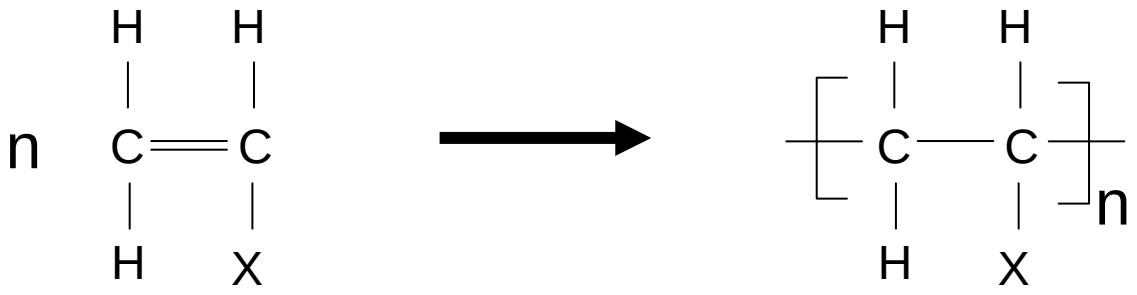
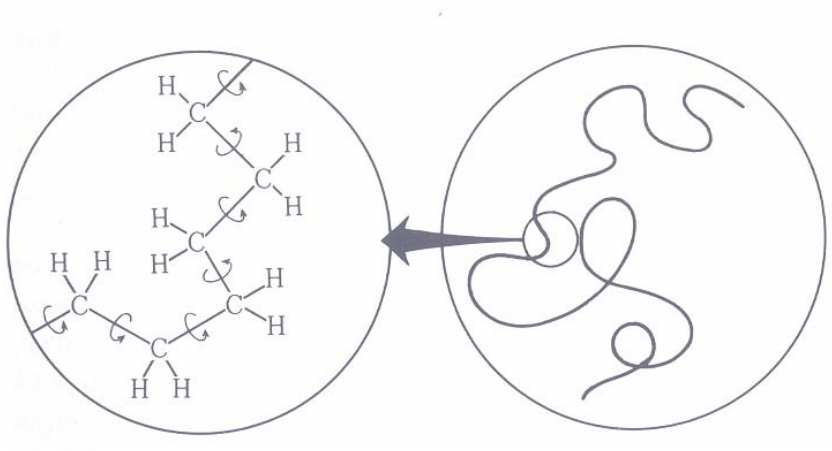
- Giant molecules and their applications
- Unusual flow behaviour
- Solids, liquids and….
- Wiggling motions

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?

Hermann Staudinger
1881-1965

- 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.

Can we live without them ?

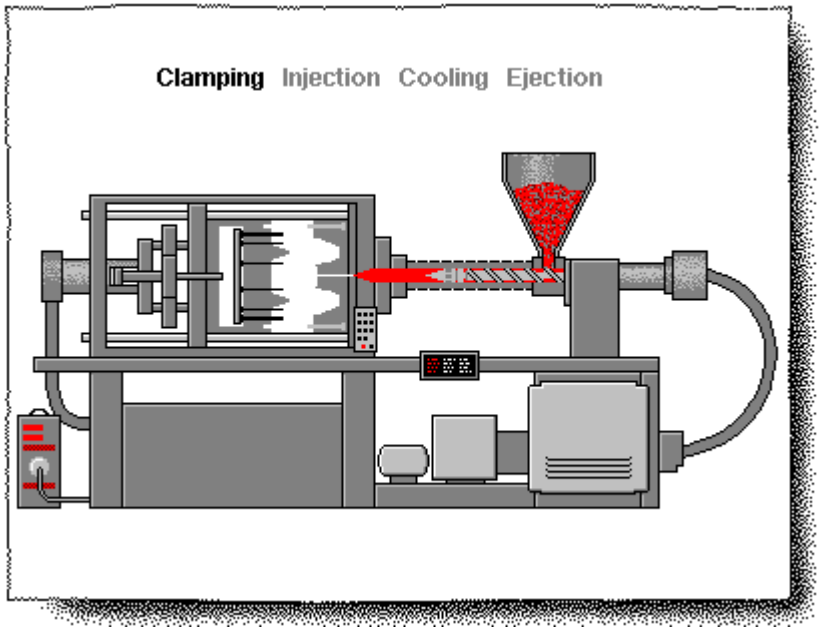
Why are they so popular?

- 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?



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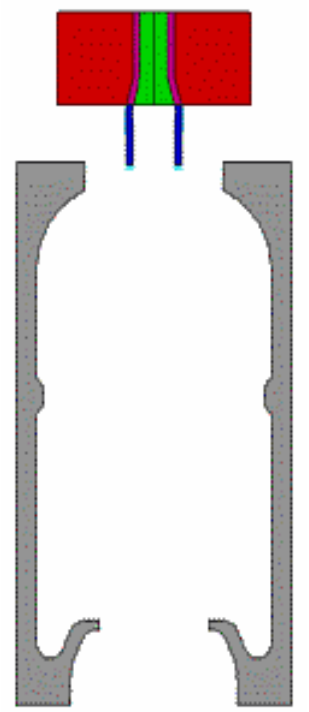
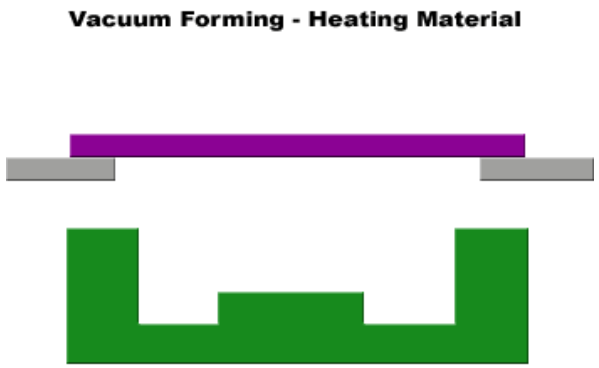




Flow behaviour demos…

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

Is this solid or liquid?

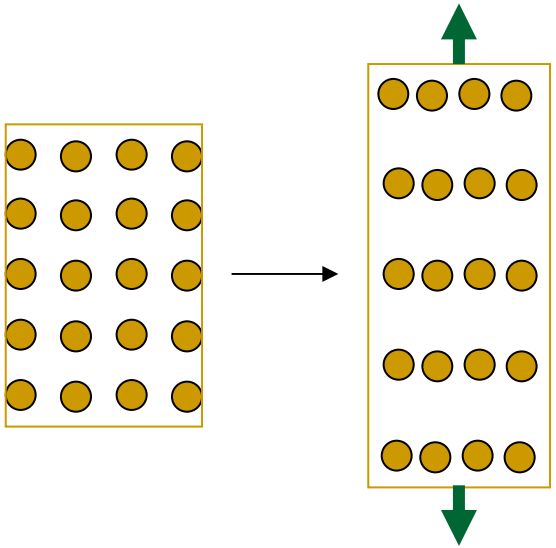
Solids (Elastic)

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

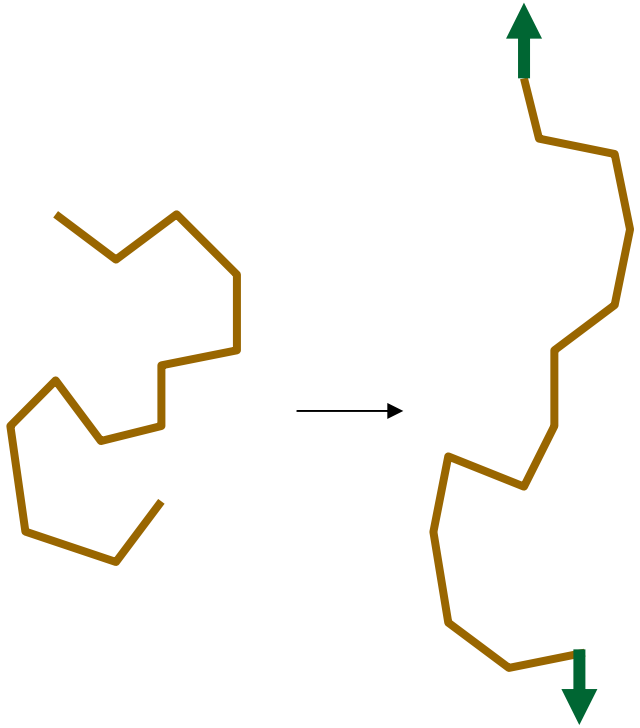
Robert Hooke
1635-1703

Homework: Can you render water elastic?

Molecular origin of elasticity

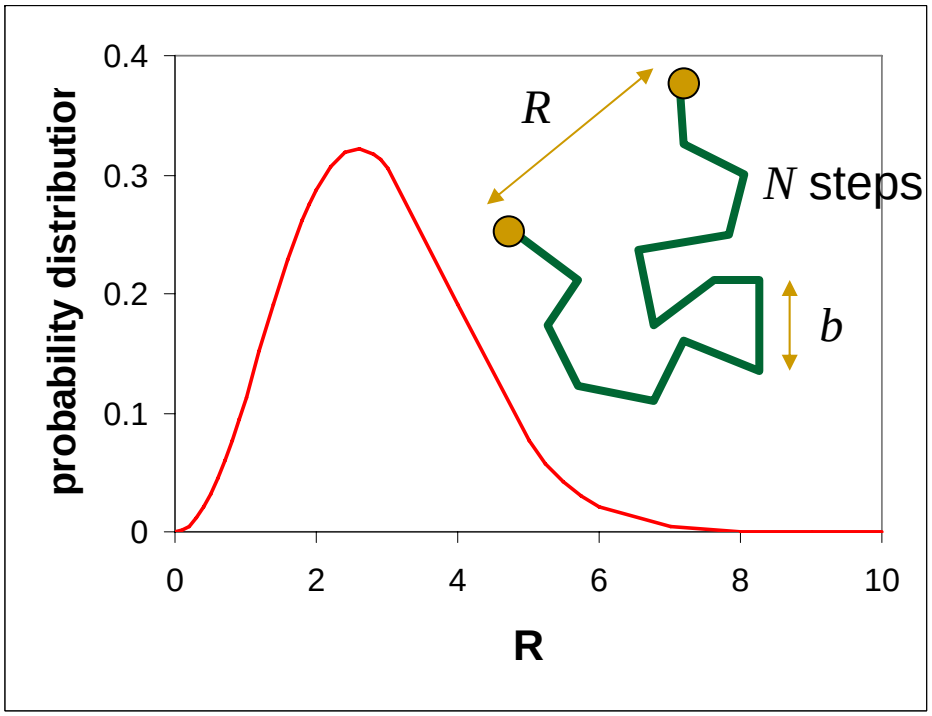


Bond stretching
Enthalpic



Bond rotation
Entropic

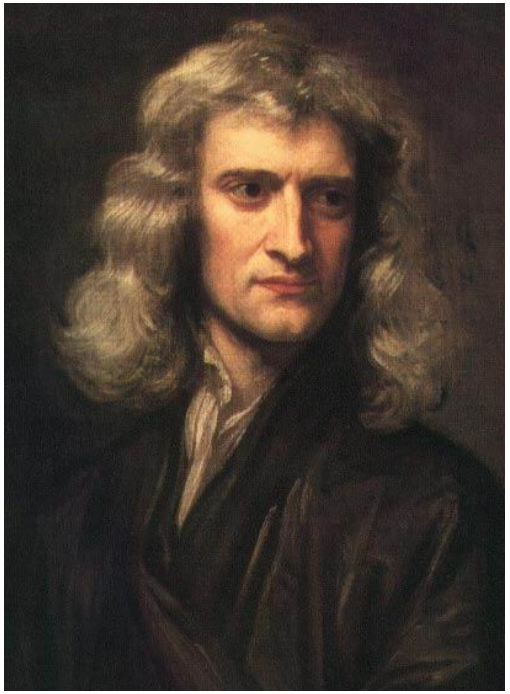
Molecular origin of elasticity



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

Liquids (Viscous)

- Zero recovery (no memory)
- Energy dissipation
- Newton's law $$F = -\eta A \frac{dv}{dy}$$



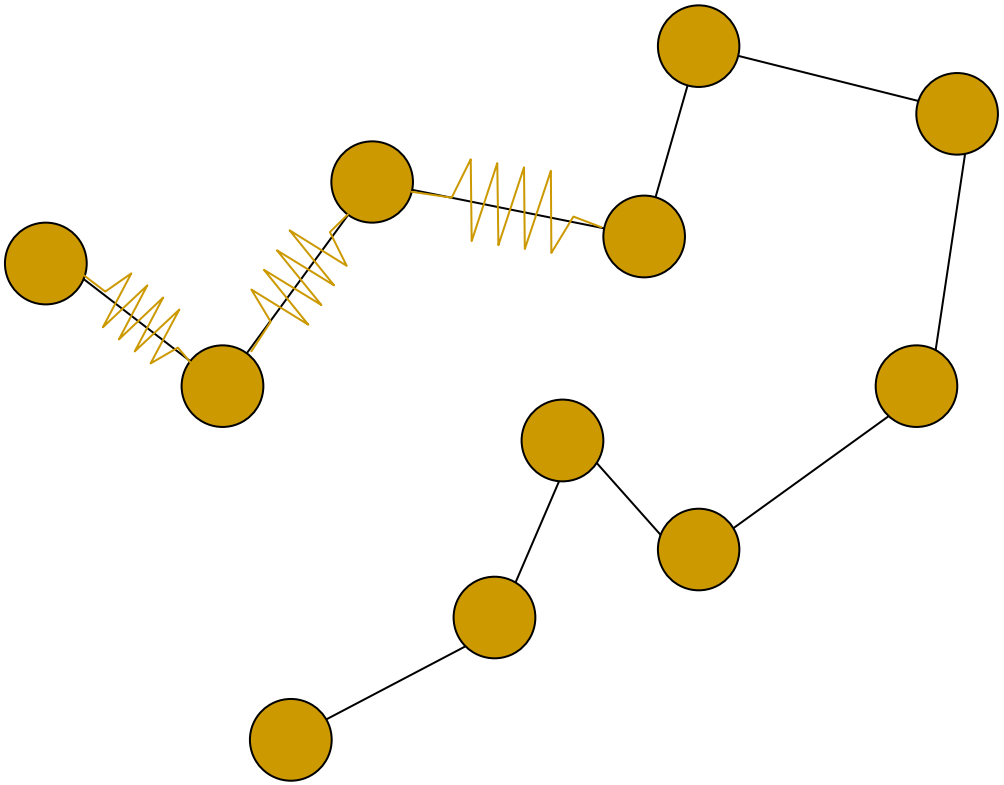
Sir Isaac Newton
1642-1727

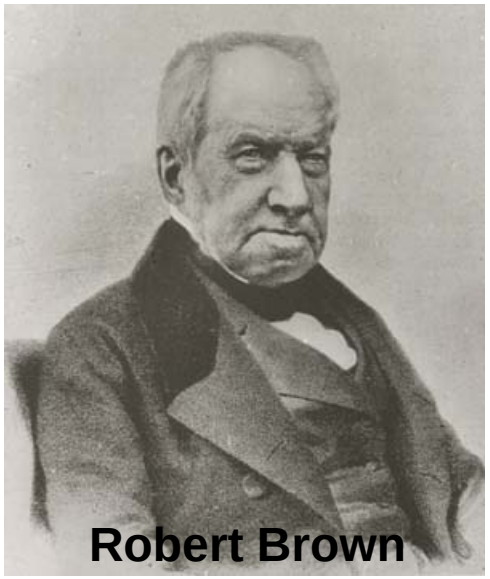
Viscoelasticity

James Clerk Maxwell
1831-1879

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

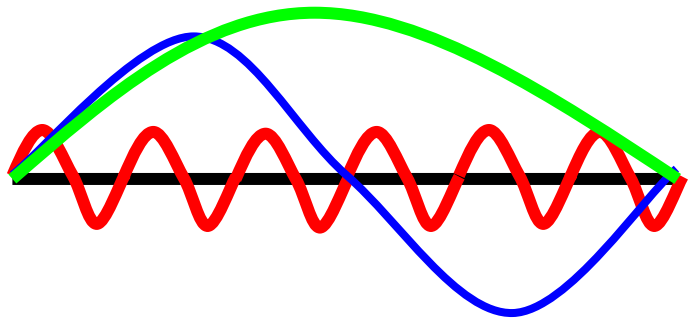
Wiggling in solutions





Robert Brown
1773-1858

Wiggling in solutions

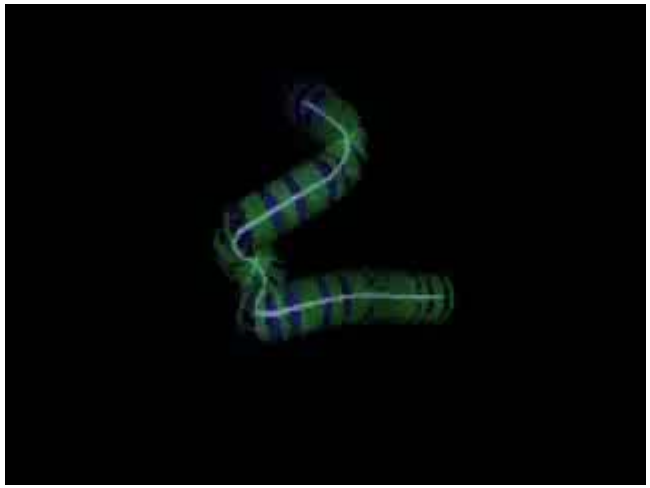


Plucked string of a guitar

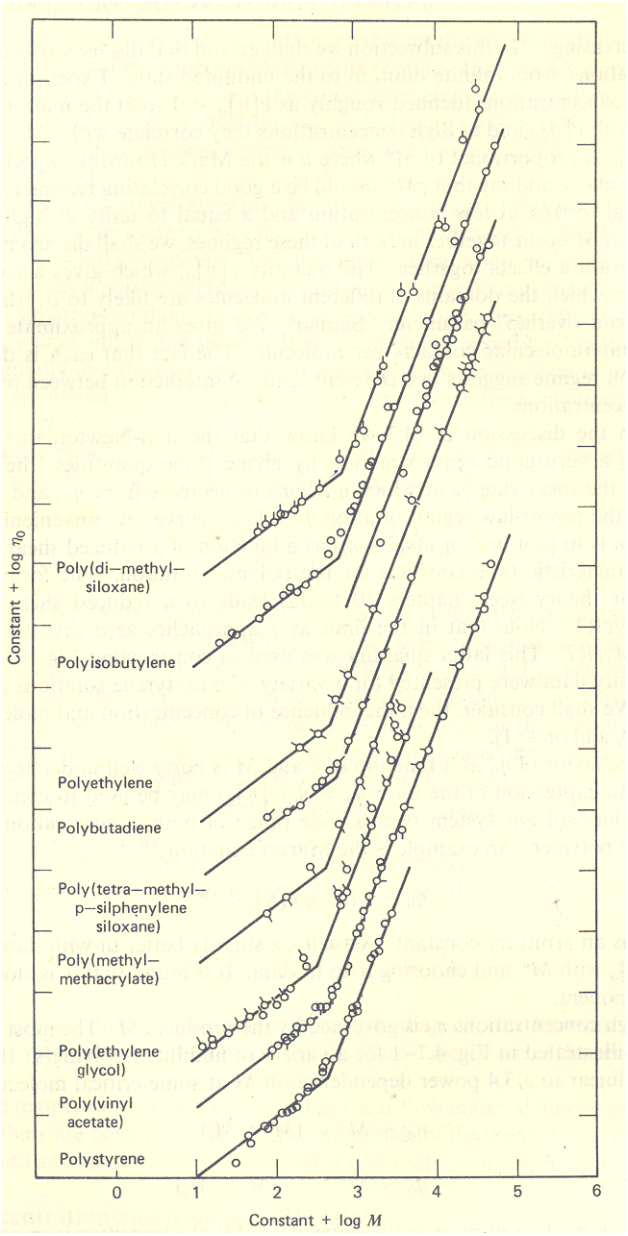
Rouse, P.E. Jr., 1953

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

Wiggling in melts



Pierre de Gennes
1932-2007



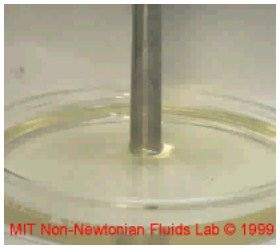
$$D_c = \frac{k_B T}{N \zeta_{bead}} \qquad \lambda = \frac{L^2}{D_c} \sim N^3$$

Why are wiggling motions important?

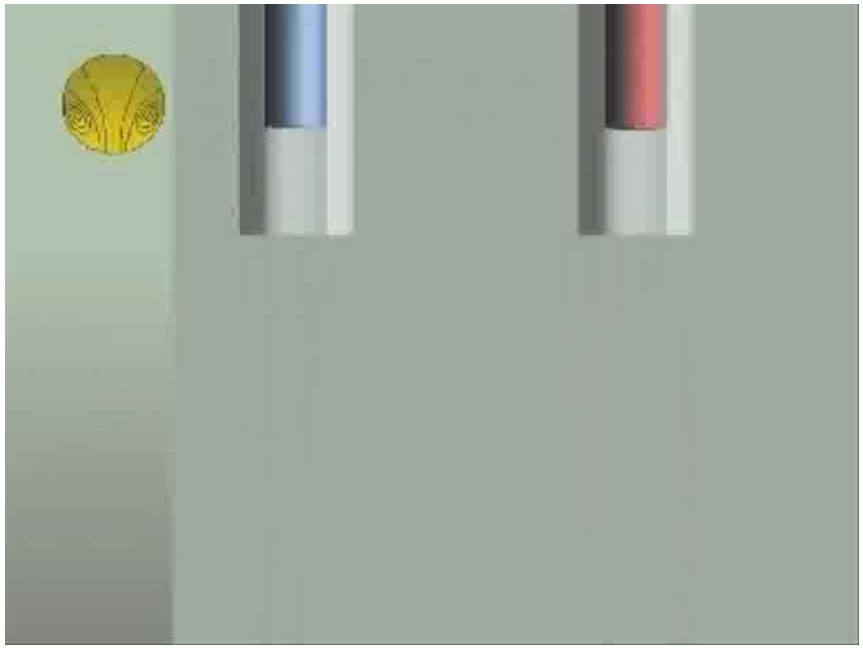
- Choosing the right polymer for an application.
- Choosing the right equipment for a polymer.
- Influence on solidification processes.
- Biological processes.

THANK YOU!

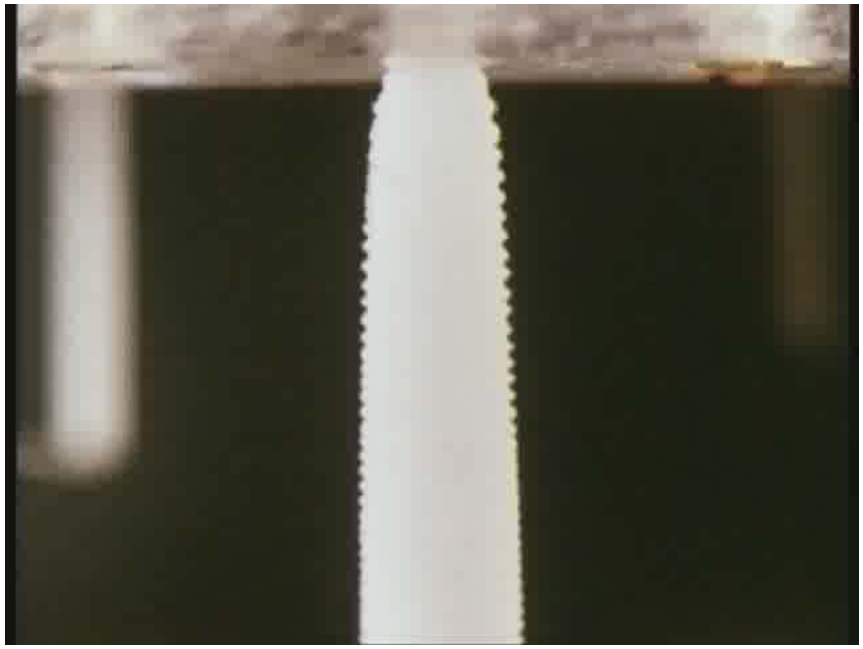
Rod climbing



Extrudate swell



Melt fracture



Filament stretching