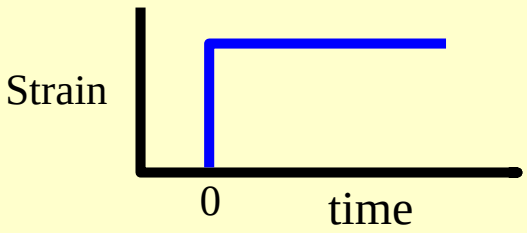
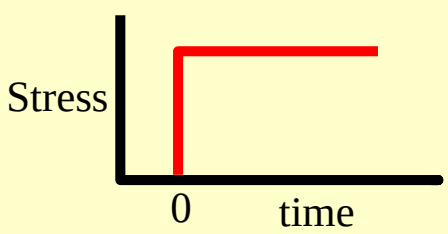
Ch 01
Introduction to complex fluids

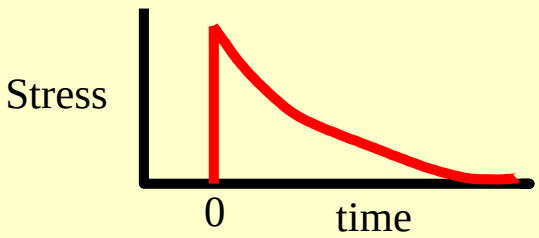
Solid ---------- Liquid

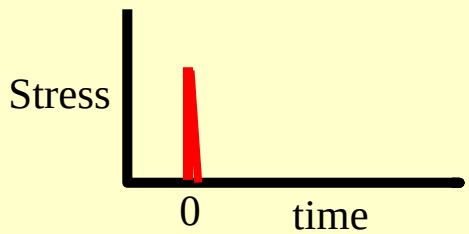
Ideal Solid ----- Most Materials ----- *Ideal Fluid*

Elastic ----- *Visco*elastic ----- *Viscous*









Solid Like ---------- Liquid Like

Ideal Solid ----- Most Materials ----- *Ideal Fluid*

Purely Elastic ----- *Visco*elastic ----- *Purely Viscous*

$$\tau = G\gamma \qquad \tau = \eta\dot{\gamma}$$

$$\tau_p + We\left(\frac{\partial \tau_p}{\partial t} + u\cdot\nabla\tau_p - \left(\nabla u\right)^T\cdot\tau_p - \tau_p\cdot\nabla u\right) = \beta\left(\nabla u + \left(\nabla u\right)^T\right)$$

$$\tau_p = f\left(\mathbf{u}, \tau_p, \lambda, \beta, \eta\right)$$

$$\mathrm{Re}\left(\frac{\partial u}{\partial t} + u\cdot\nabla u\right) = -\nabla p + \nabla\cdot\tau_p + (1-\beta)\nabla^2 u$$

$$\nabla\cdot u = 0$$

Time-dependent Viscoelastic Behavior

- Old Testament Prophetess who said :
  "The Mountains Flowed before the Lord"

- Everything Flows if you wait long enough!

- Deborah Number, De - The ratio of a characteristic time of a material (τ) to a characteristic time of the process (T)

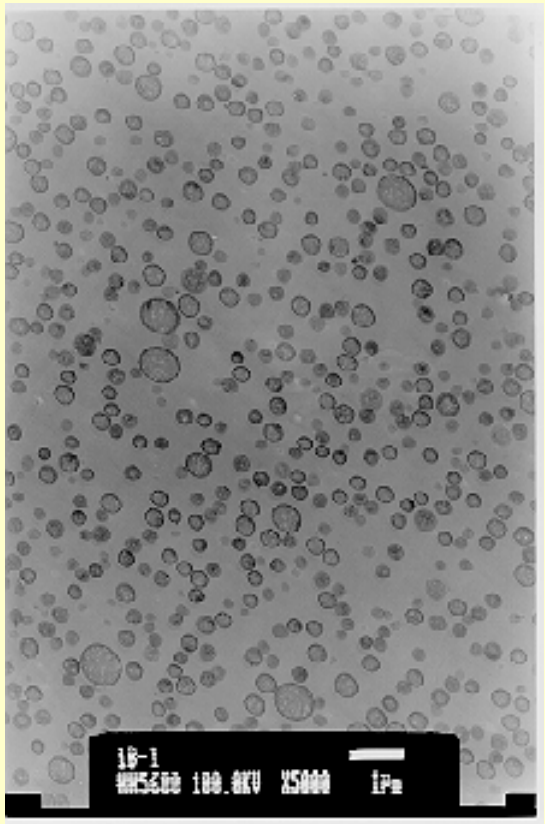
$$De = \tau/T$$

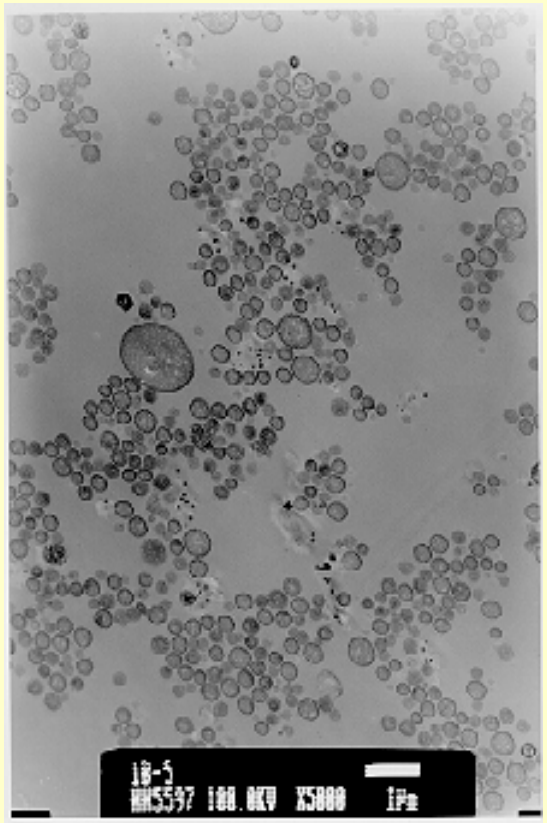
Rheology

- The science of flow and deformation of matter (complex fluids)
- Viscoelastic
- Deborah number $De = \tau/T$
- Processing technology

Mathematical theology

ABS

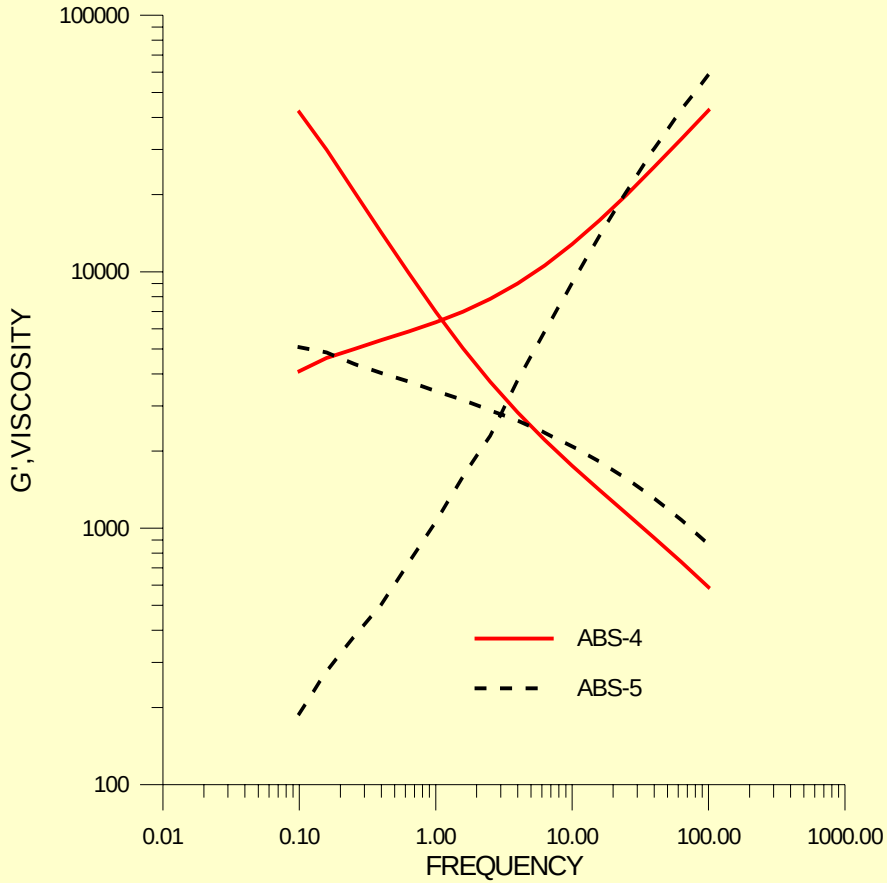




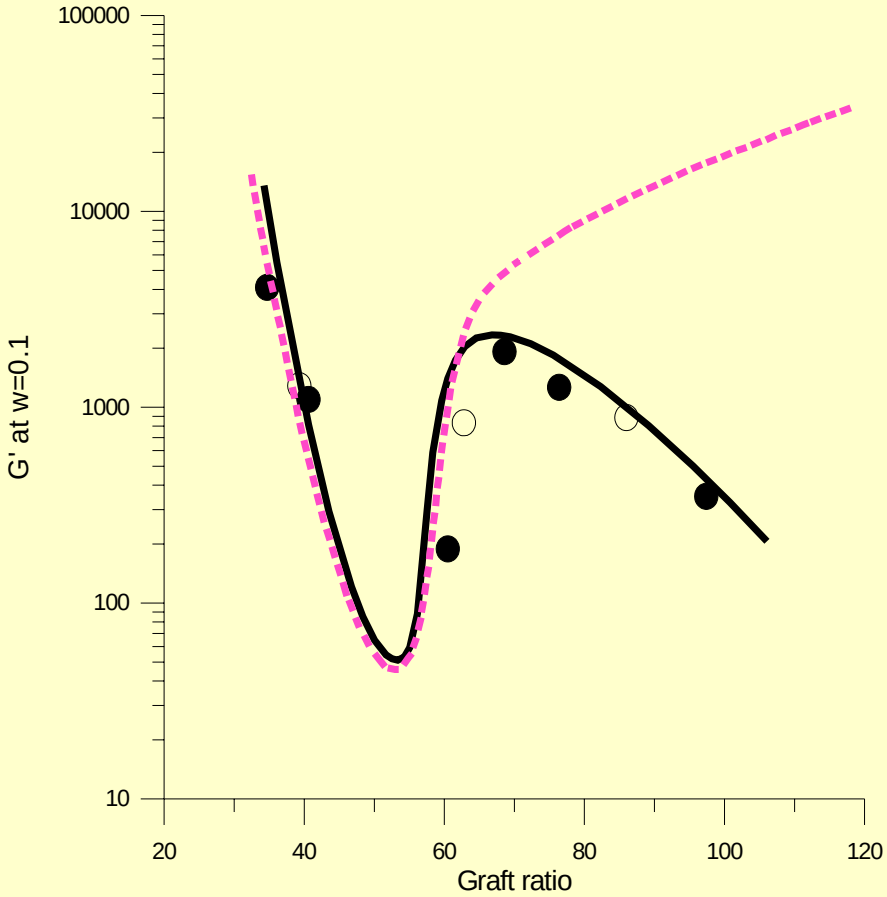
ABS (Acrylonitrile-Butadiene-Styrene)

	Particle size	Gel content	Graft ratio	Impact strength	Hard-ness	Tensile strength	Flexural strength	VST	gloss
ABS-4	3075	86	42	26.7	96.4	402	582	93.7	103.9
ABS-5	3100	82	69	24.1	95.3	393	567	95.1	101.7

G’ and η* of ABS


100000
10000
1000
100
G',VISCOSITY
0.01
0.10
1.00
10.00
100.00
1000.00
FREQUENCY
ABS-4
ABS-5

G’ vs. graft ratio



Sheet grade 불량
(냉장고 내상용 ABS)

- 냉장고 내상용: 고부가가치, 대량공급
- Sheet 표면 불량 (gel)
- 1회 test에 resin 약 3톤 소요
- Test 시 문제없으나 양산 공급시 문제발생- Claim
- 수지가 압출기 내에서 체류되어 발생하는 문제로 추정

- 문제원인분석
- 평가방법확보
- 문제해결방법 및 전략???

Competition with HIPS

- 냉장고 내상용 ABS,HIPS 반분
- ABS는 외관 우수, HIPS는 가격 경쟁력
- 판가: ABS 1500$ / MT, HIPS 800$ / MT
- 두께: ABS 3.5t, HIPS 4-5t
- 가격경쟁 심화
- ABS 사용업체는 HIPS로 전환하고자 함

- Sheet 두께 down
- 진공성형성 향상
- 접근방법 및 전략???

Kingdom of rheology

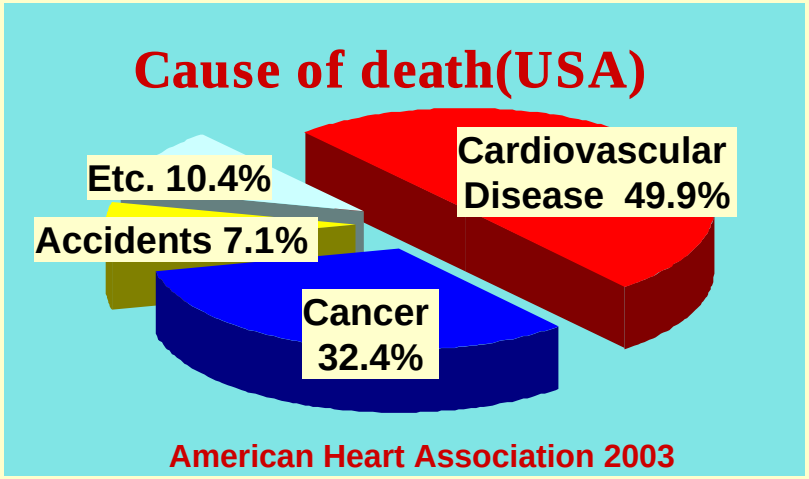
14th ICR, Aug.22-27, Seoul

- Computational rheology
- Flow instability
- Foams, emulsions & surfactants
- Foods & biomaterials
- Materials processing
- Microstructural modeling
- Nanorheology & microfluidics
- Non-Newtonian fluid mechanics
- Polymer melts
- Polymer solutions
- Rheometry & experimental methods
- Solids & composites
- Suspensions & colloids

Challenges

- Biorheology
  - Hemorheology, microfluidics
- IT rheology
  - ACF rheology, coating
- Nanorheology
  - Clay, CNT
- Modeling and simulation

Biorheology



Extra-corporeal life supporter

RBC deformation and hemolysis

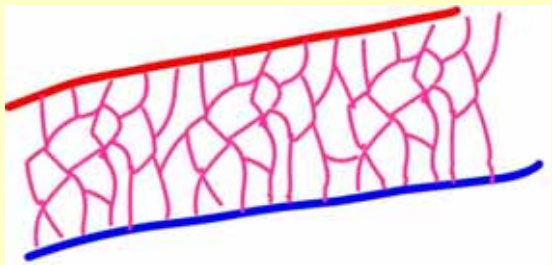
Diabetes Association

- Most diabetics have hyperviscosity by one or other mechanism. (Dintenfass L, 1989)

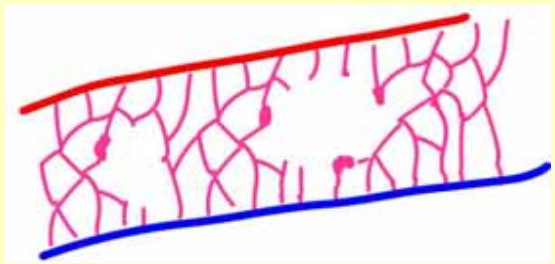
- The Complication of diabetics

  (Diabetic Retinopathy, Nephropathy, Nervous Diease)

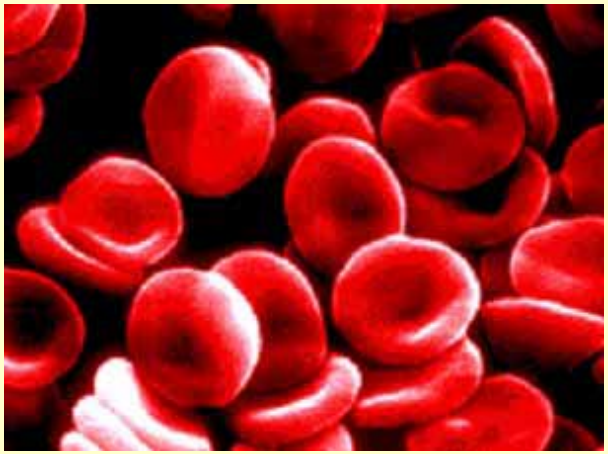
Diabetic Retinopathy



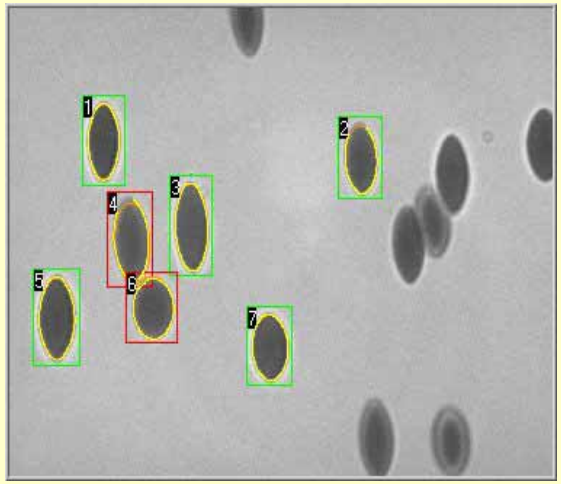
Heathy retinal capillaries

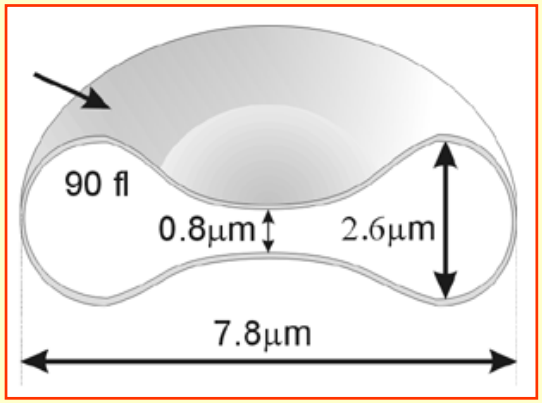


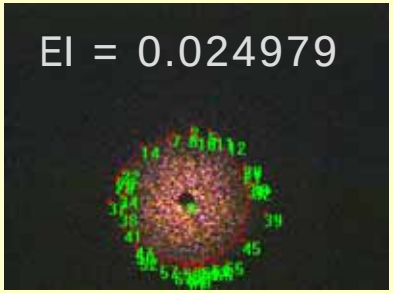
Diabetic retinal capillaries



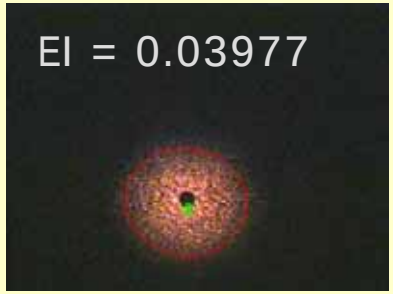
In pure
shear flow



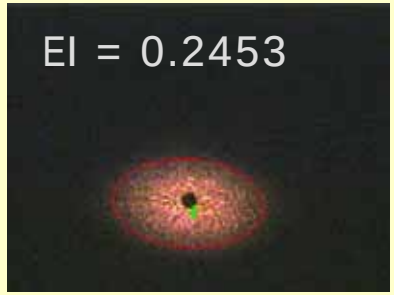




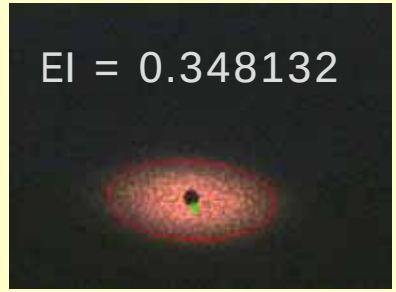
aspect ratio = 1.05
major axis = 107.9
minor axis =102.7



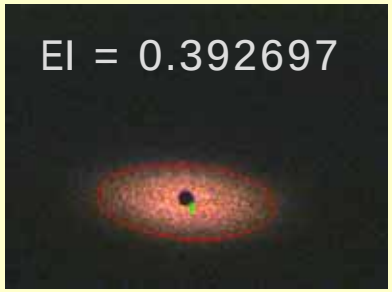
aspect ratio = 1.12
major axis = 97.9
minor axis = 87.7



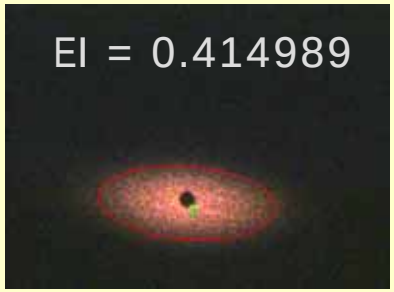
aspect ratio = 1.65
major axis = 120.8
minor axis = 73.2



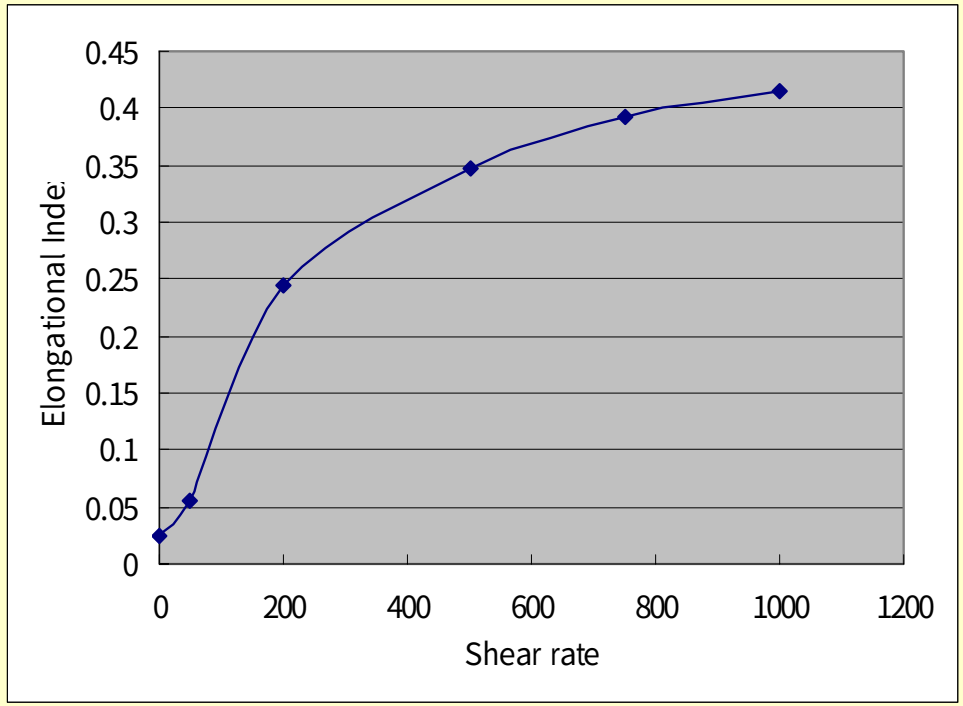
aspect ratio = 2.0681073
major axis = 134.48761
minor axis = 65.029320



aspect ratio = 2.29
major axis = 140.1
minor axis = 61.1



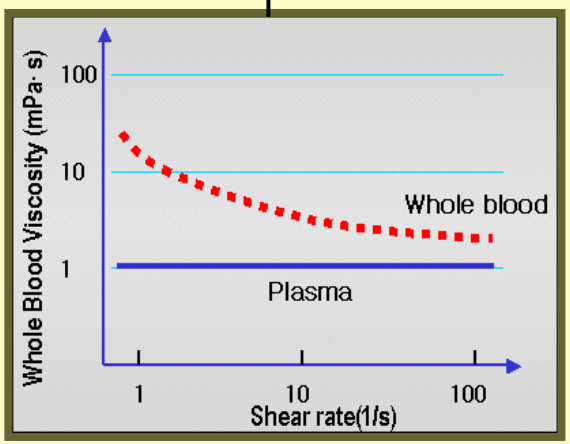
aspect ratio = 2.42
major axis = 145.2
minor axis = 60.0

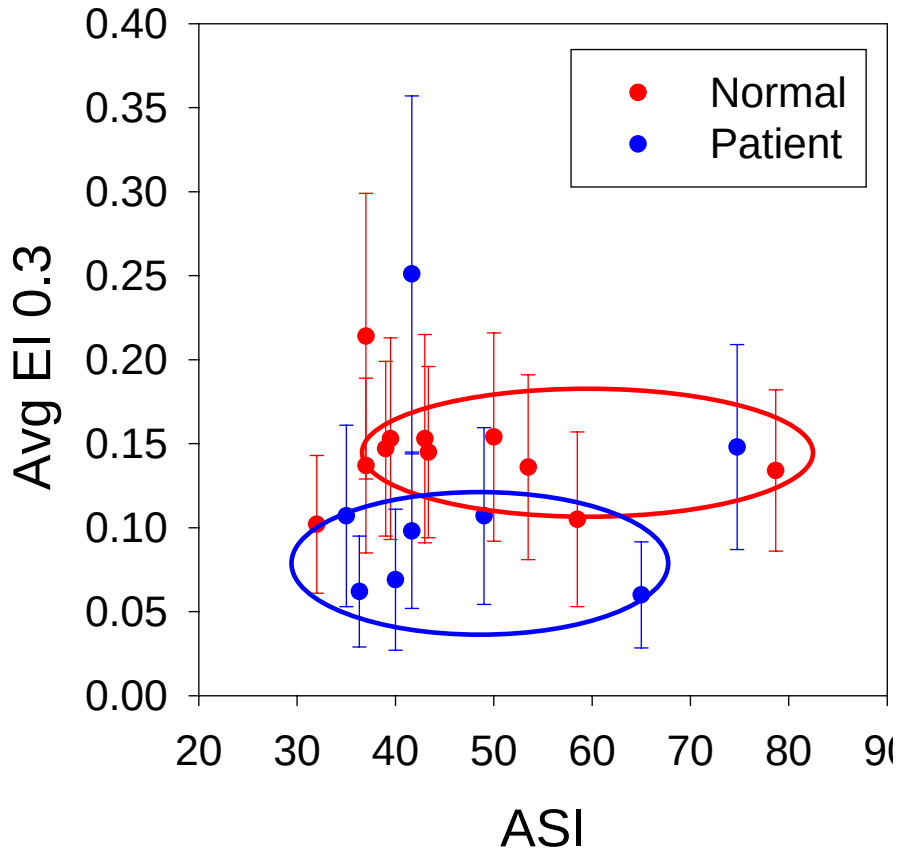


Early diagnosis of heart disease

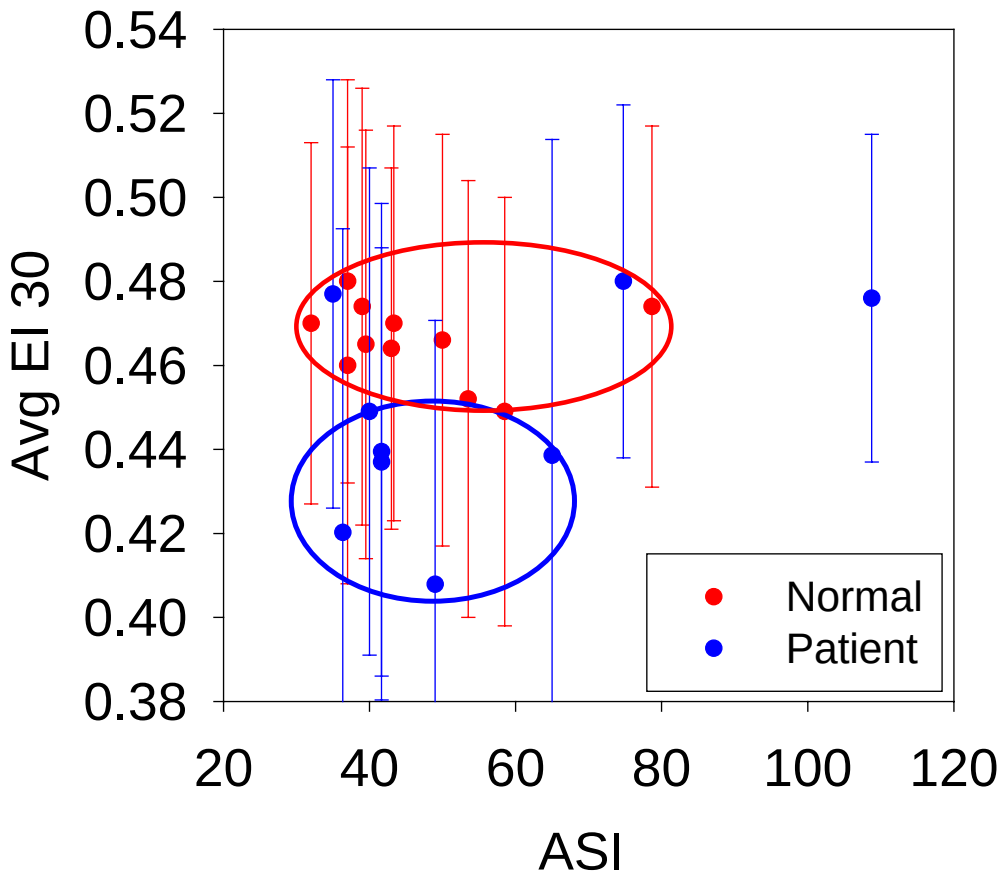
BLOOD VISCOSITY

plasma viscosity ⇔ erythrocyte aggregation ⇔ hematocrit | erythrocyte deformability | leukocytes

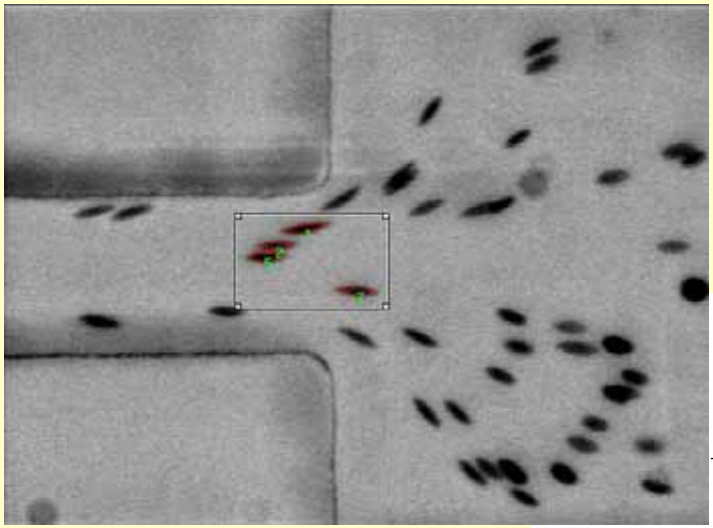


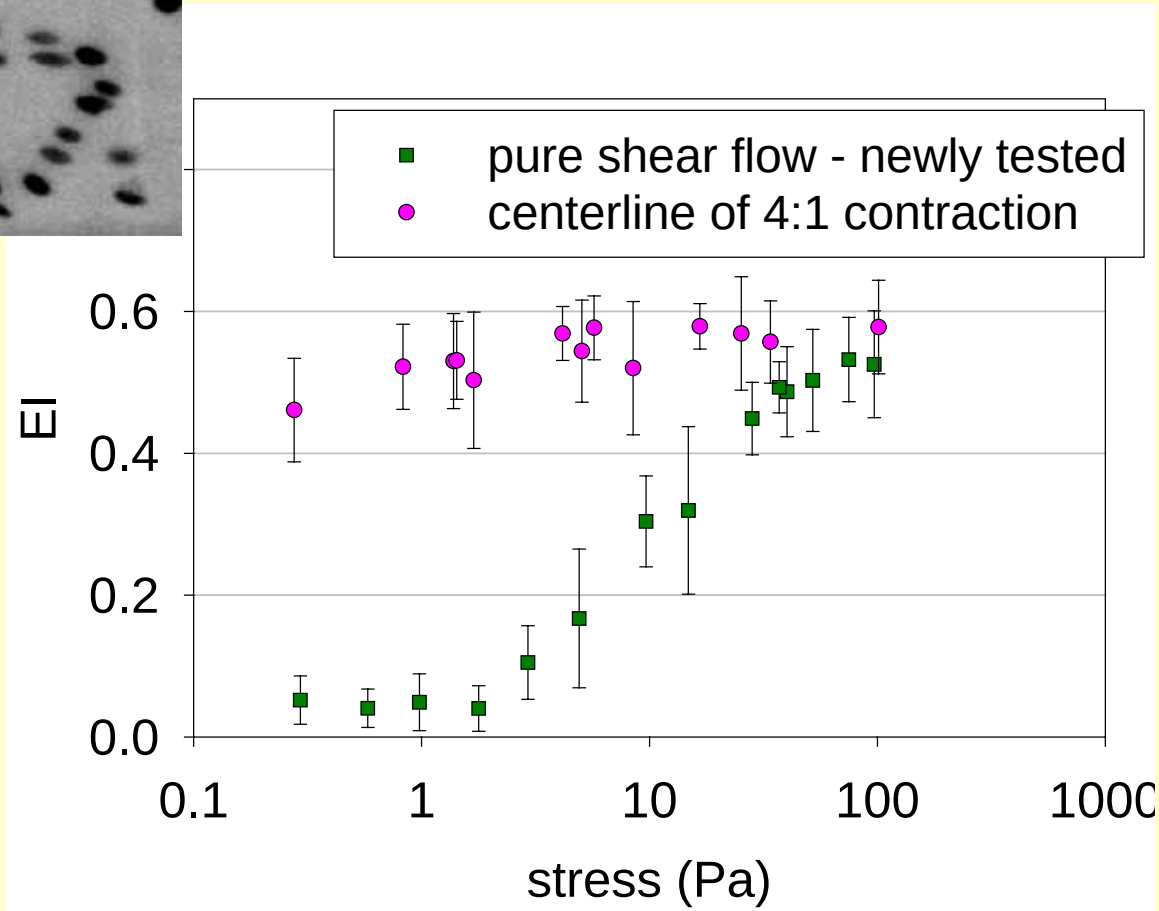


Shear rate= 0.3



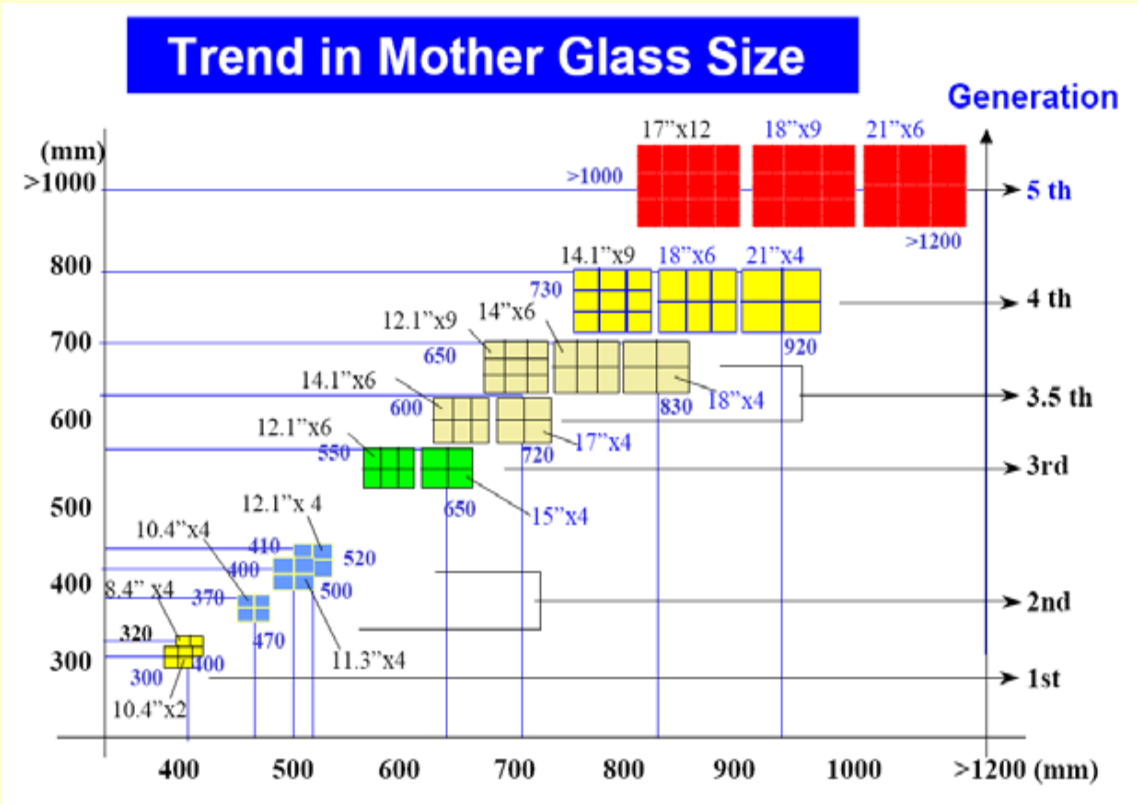
Shear rate= 30

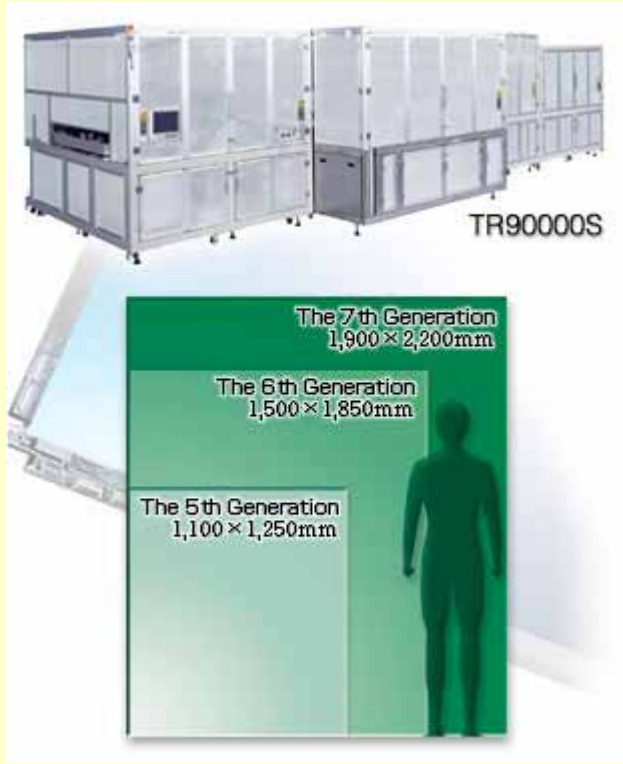


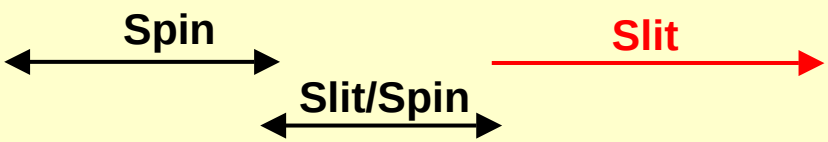

pure shear flow - newly tested
centerline of 4:1 contraction
EI
0.0
0.2
0.4
0.6
0.1
1
10
100
1000
stress (Pa)

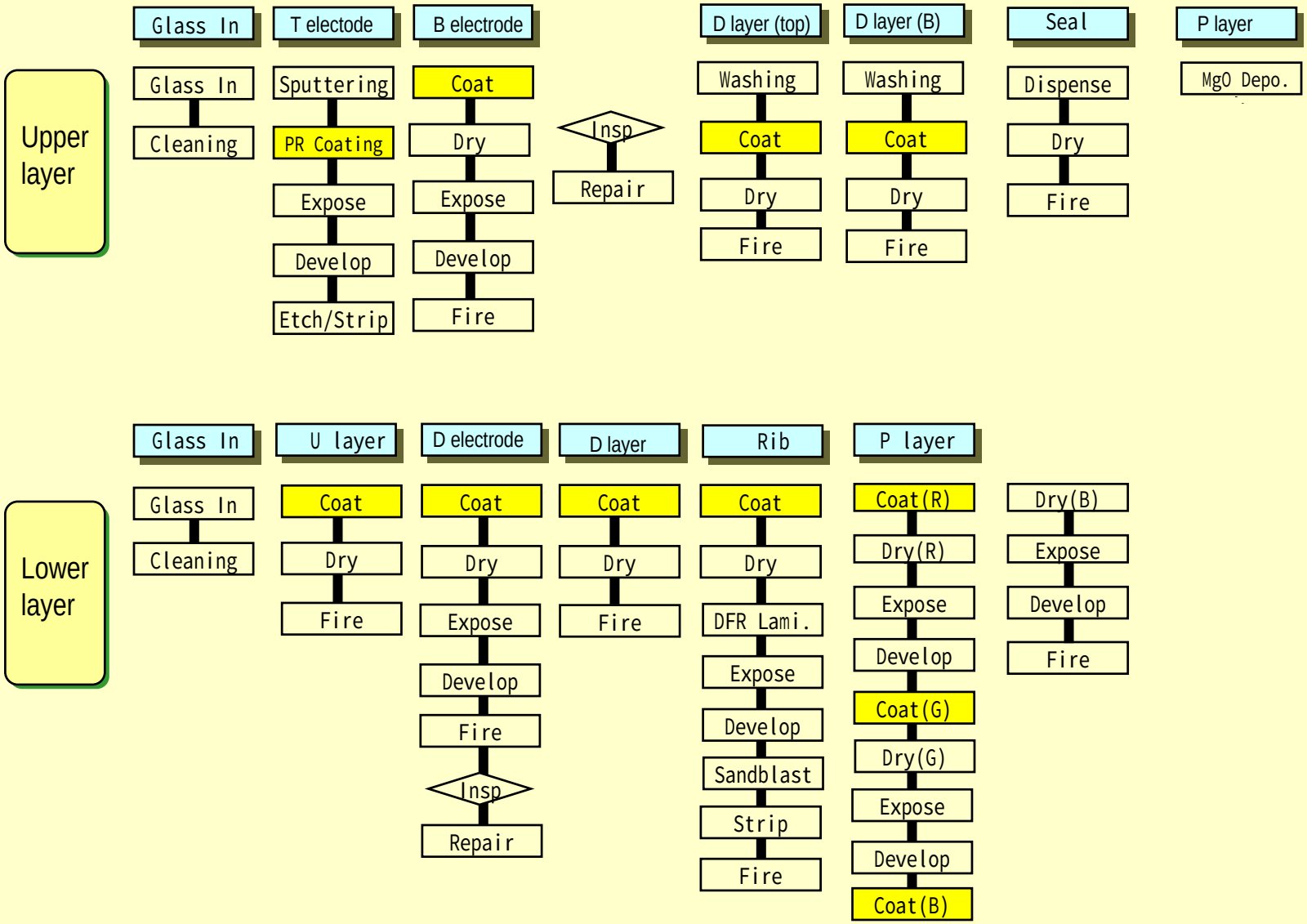
IT rheology

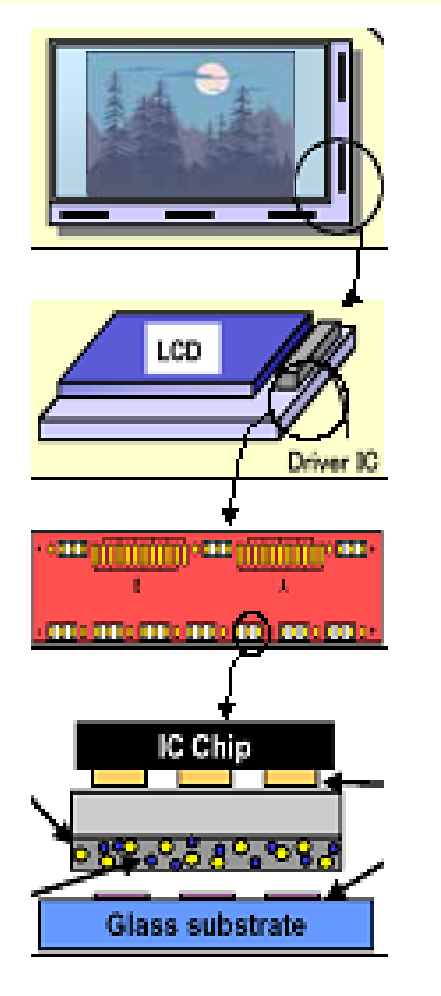
Glass size vs. Coating Method








Upper layer
Glass In
T electode
B electrode
D layer (top)
D layer (B)
Seal
P layer
Glass In
Cleaning
Sputtering
PR Coating
Expose
Develop
Etch/Strip
Coat
Dry
Expose
Develop
Fire
Insp
Repair
Washing
Coat
Dry
Fire
Washing
Coat
Dry
Fire
Dispense
Dry
Fire
MgO Depo.
Lower layer
Glass In
U layer
D electrode
D layer
Rib
P layer
Glass In
Cleaning
Coat
Dry
Fire
Coat
Dry
Expose
Develop
Fire
Insp
Repair
Coat
Dry
Fire
Coat
Dry
DFR Lami.
Expose
Develop
Sandblast
Strip
Fire
Coat(R)
Dry(R)
Expose
Develop
Coat(G)
Dry(G)
Expose
Develop
Coat(B)
Dry(B)
Expose
Develop
Fire



- 3-dimensional
- Time dependent
- Squeezing flow
  (pseudo steady state)
- Non-isothermal
  (temp distribution with
  time and position)
- Curing reaction
- Particulate flow
- Complex flow field
  and geometry

→ particle and stress distributions

typical rheology problem

Nanorheology

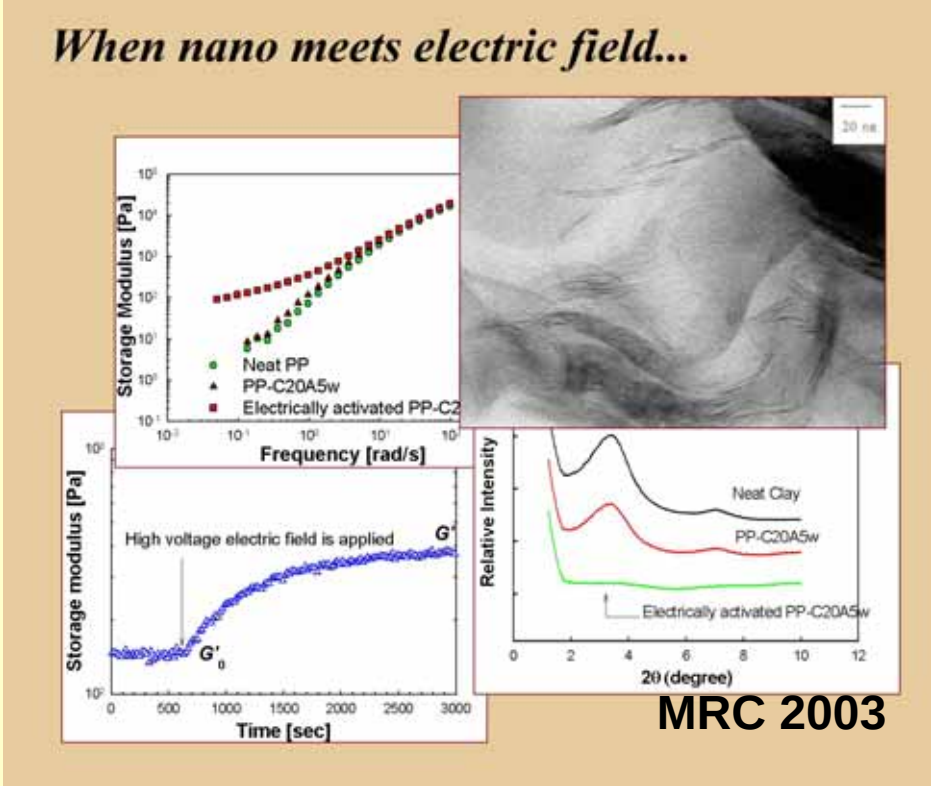
PP/clay

+

Electric field

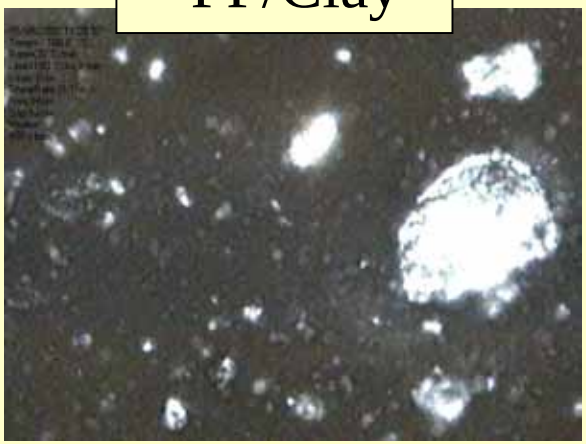
=

Exfoliation

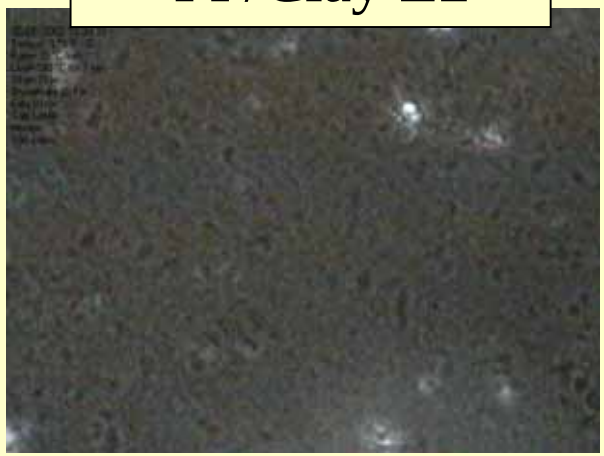


Why? What happens?

•PP/Clay

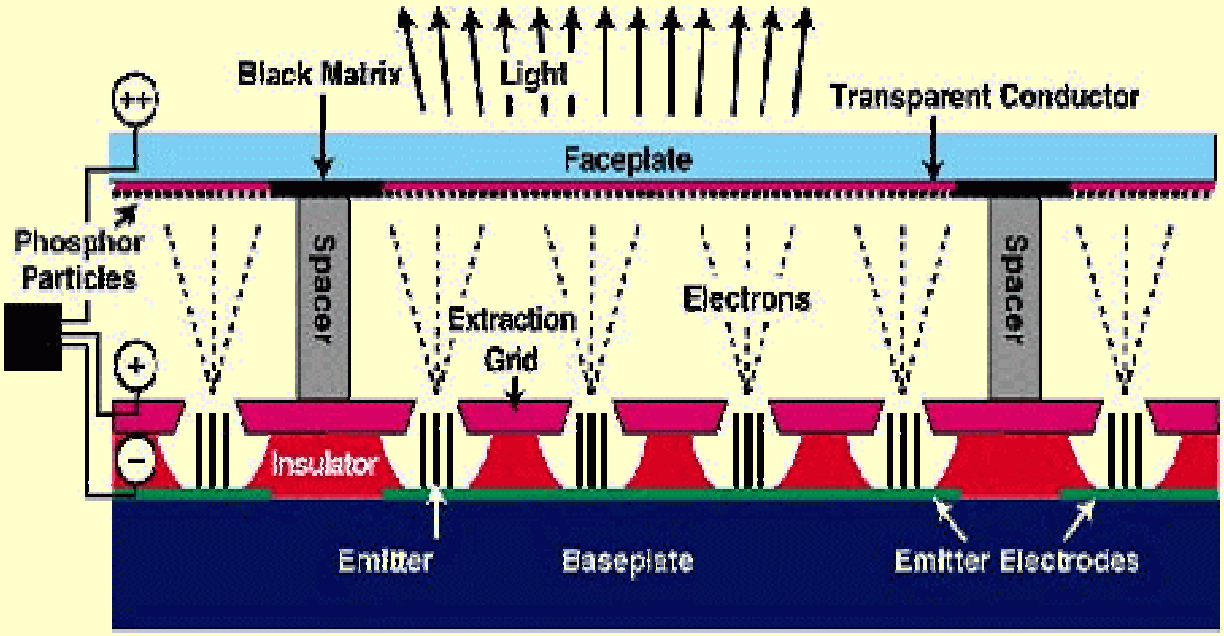


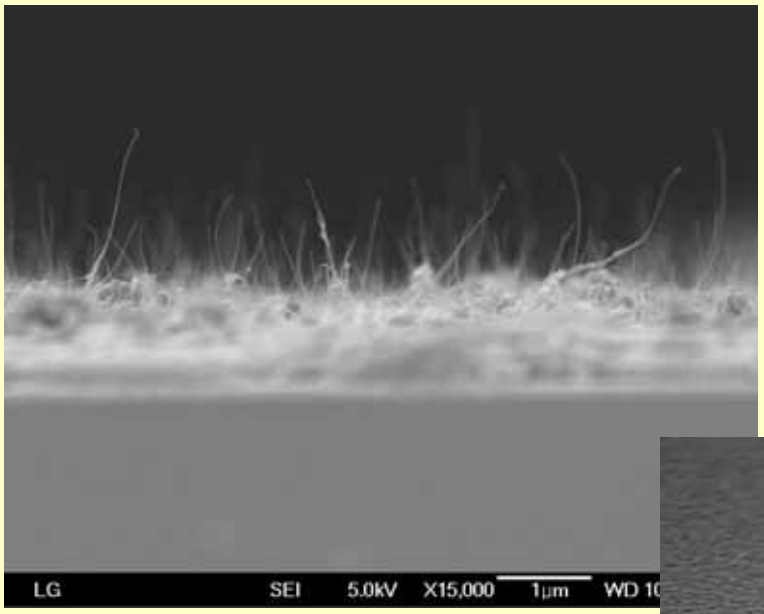
•PP/Clay E2

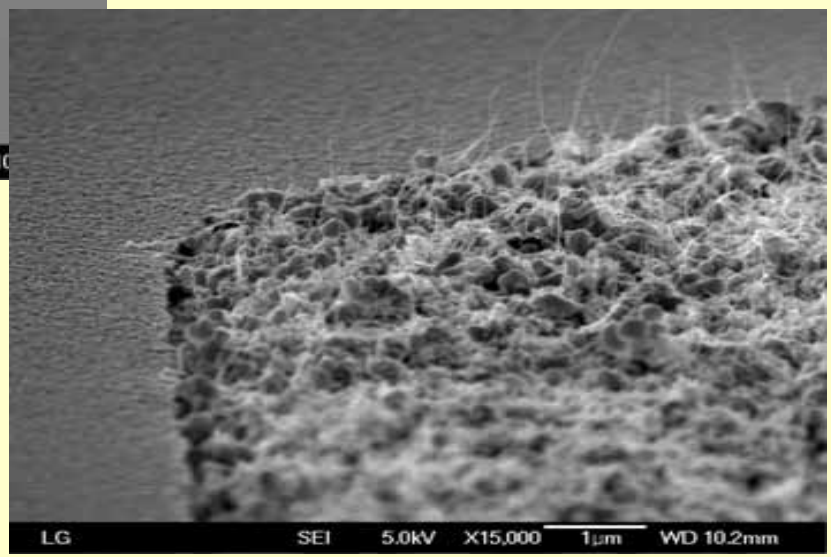


Optics measured at 180C. (x 100)

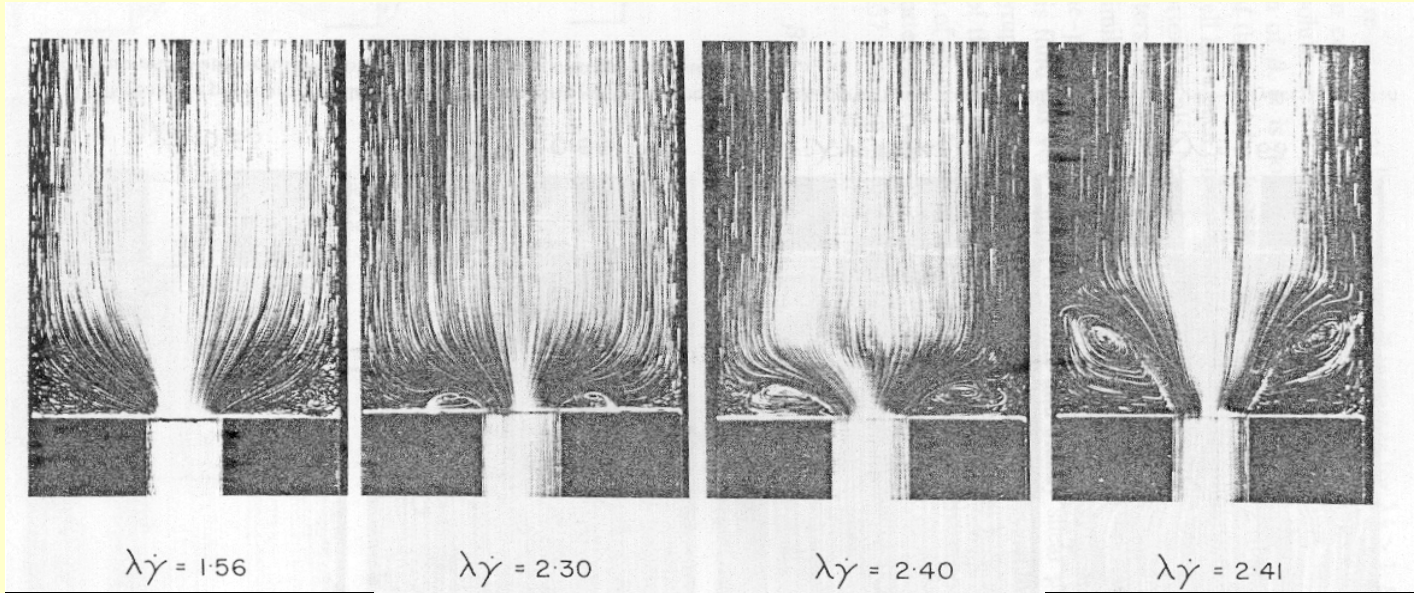
layer-stacking destruction
separation of silicate layers


Black Matrix
Light
Transparent Conductor
Faceplate
Phosphor Particles
Spacer
Extraction Grid
Electrons
Spacer
Insulator
Emitter
Baseplate
Emitter Electrodes

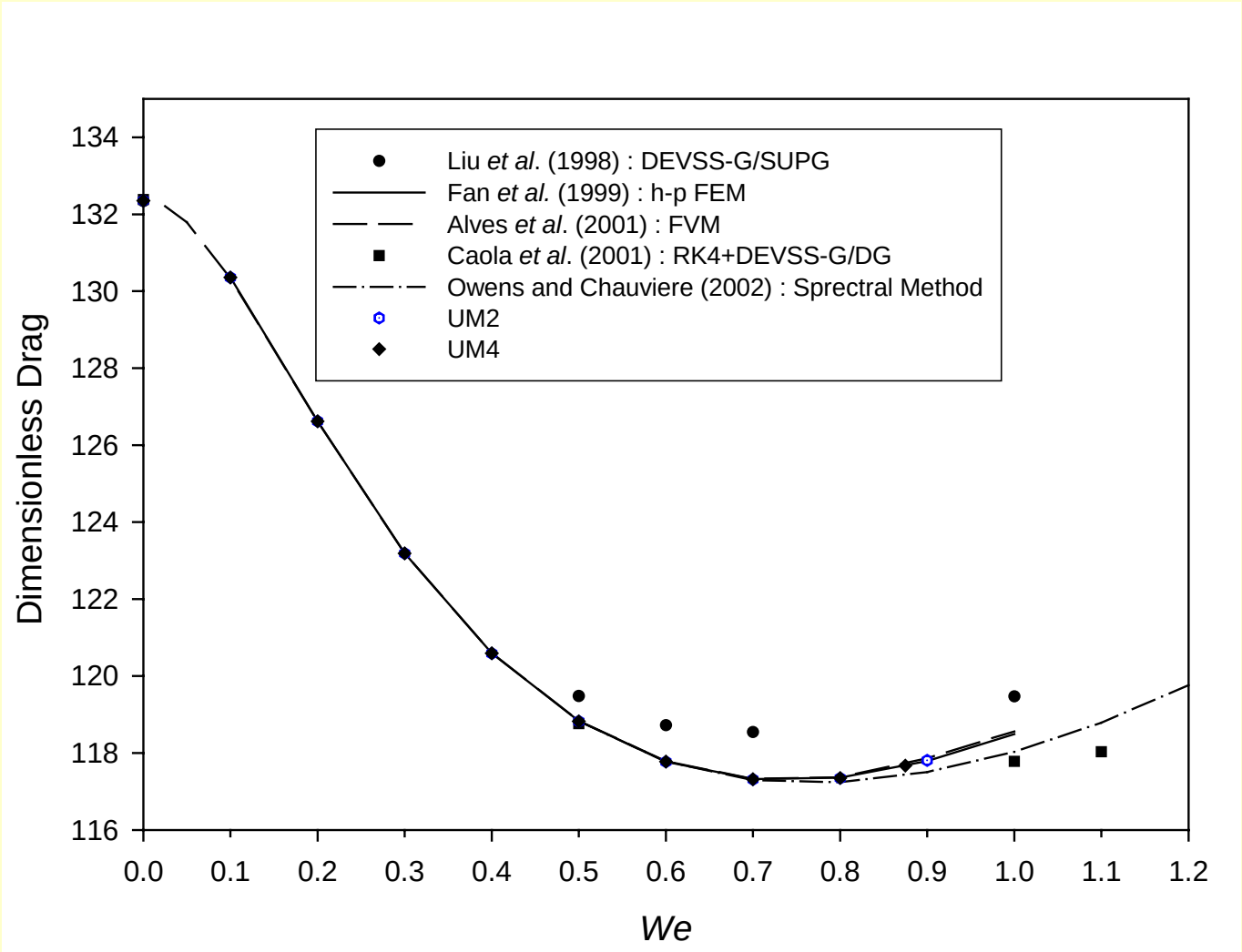

LG SEI 5.0kV X15,000 1μm WD 1


LG SEI 5.0kV X15,000 1μm WD 10.2mm

Simulation & modeling



Flow past a confined cylinder



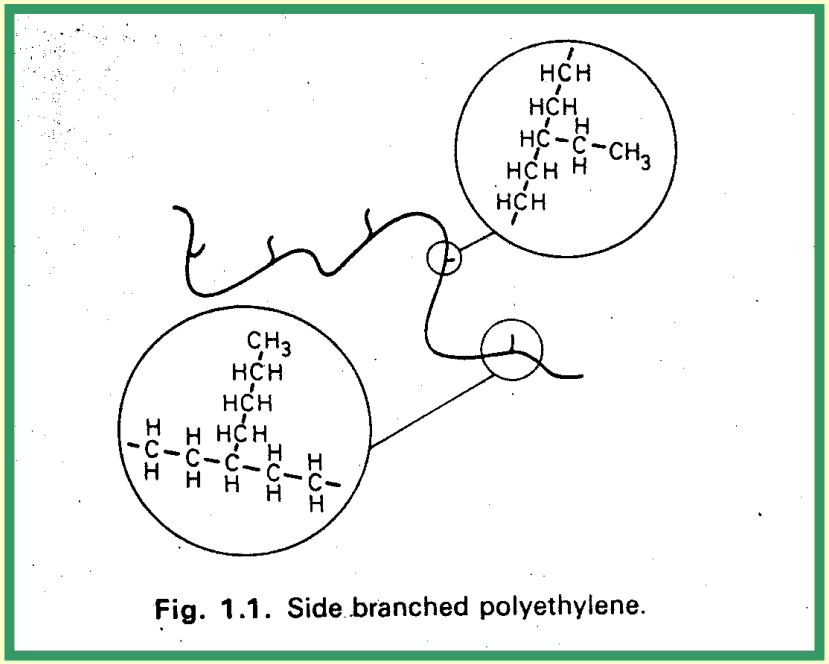
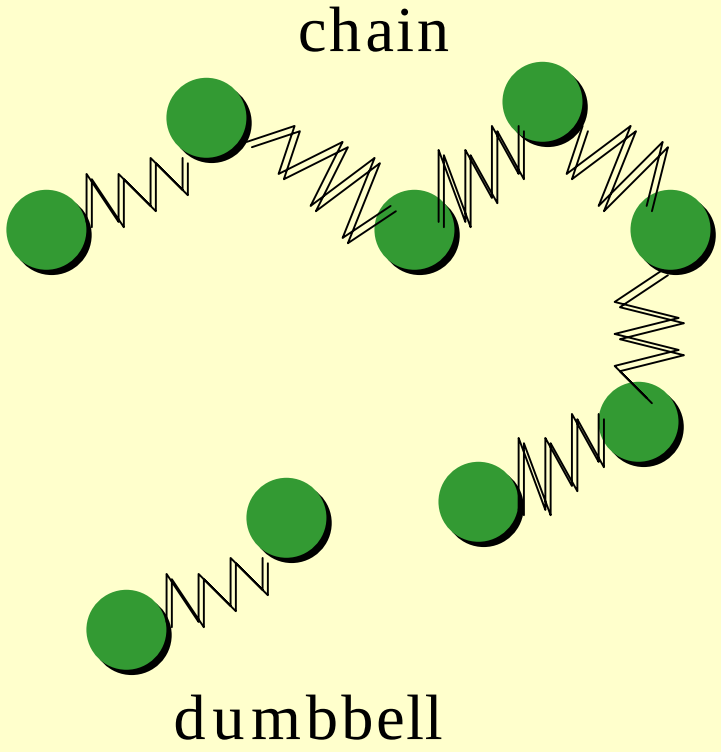
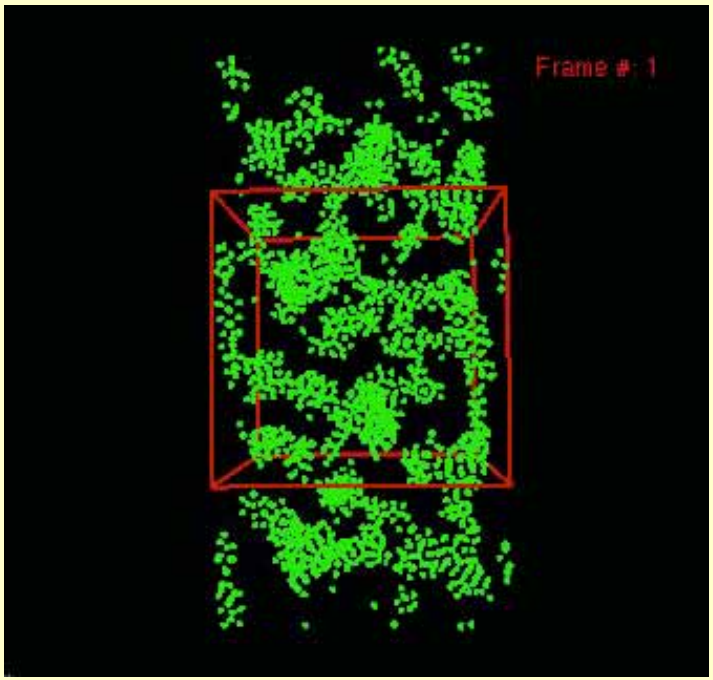
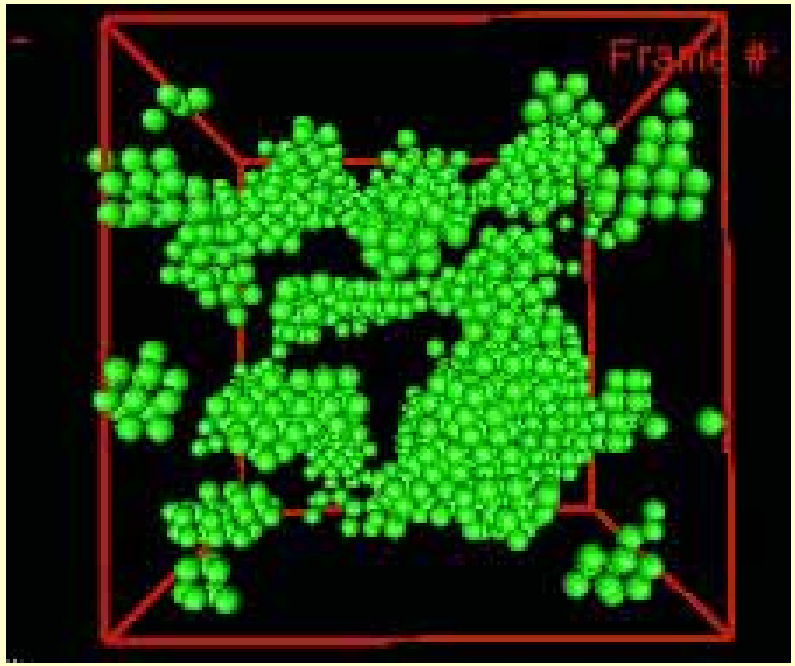


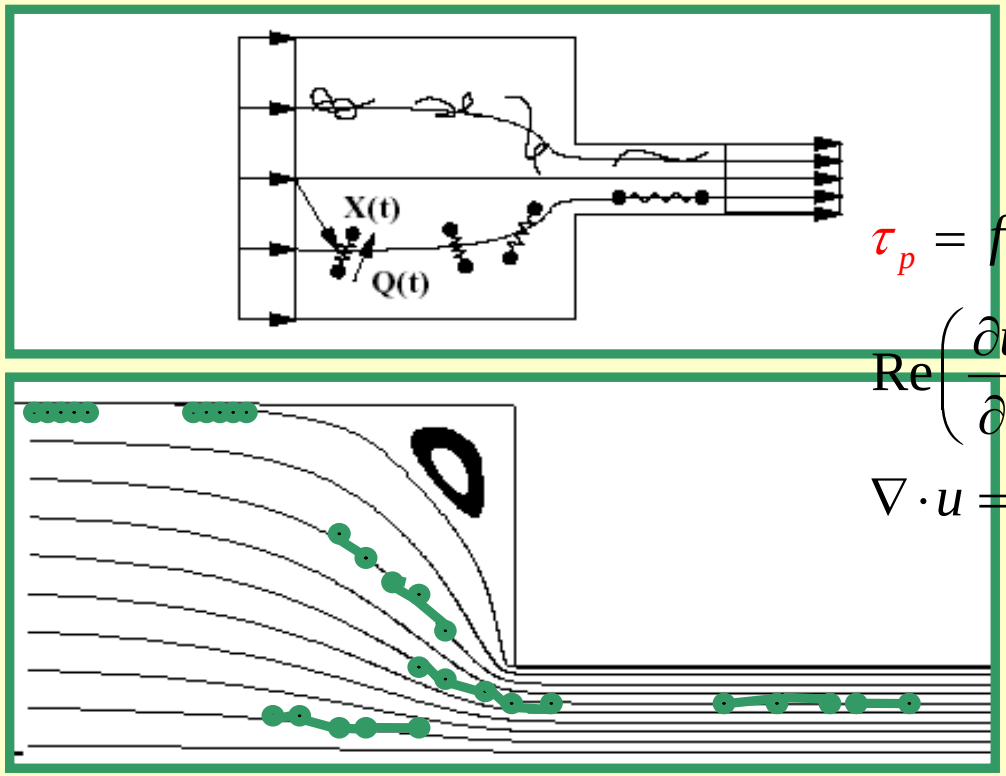
Fig. 1.1. Side branched polyethylene.



Modeling: BD, DPD, FPD, LB,…







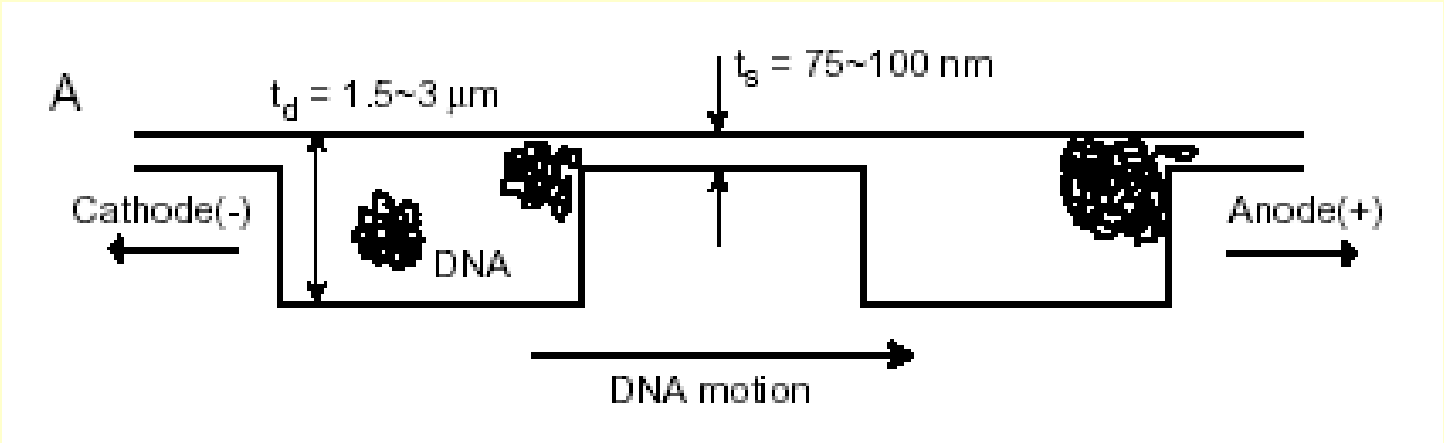
$$\tau_p = f\left(\mathbf{u}, \tau_p, \lambda, \beta, \eta\right)$$

$$\mathrm{Re}\left(\frac{\partial u}{\partial t} + u \cdot \nabla u\right) = -\nabla p + \nabla \cdot \tau_p + (1-\beta)\nabla^2 u$$

$$\nabla \cdot u = 0$$

Critical to precise process control

- precision injection, coating, micro-channel flow …



- Separation of long DNA molecules in a microfabricated entropic trap array, Science, 2000.