Aging and Rheology in Soft Materials
Fielding, Sollich, and Cates
Journal of Rheology, 2000

Glossary of Select Terms

Term
Quote from article
Definition

Soft glassy material (SGM)
Material with structural disorder and metastability (e.g. wet foams, emulsions, pastes, and slurries)

Soft glassy rheology (SGR) model
Based on Bouchaud's trap model of glassy dynamics, with two modifications

1. introduce strain contribution
2. replace thermodynamic temperature by an effective (noise) temperature

- Includes mesoscopic, heterogeneous elements
- Continuous variables of stress and strain apply.
- Does not predict, nor allow for normal stress
- Scalar model which relates shear stress to shear strain
- Locally affine deformation ($\dot{\gamma} = \dot{l}$)
- Model behaves as elastic solid with shear modulus k, but then yield events allow liquidity and stress relaxation

Time translation invariance (TTI):
Same properties (or results) if test is performed at a different time

Affine
Each element follows affinely the applied shear
Strain is the same everywhere (compatibility is satisfied)

Metastable
Existence of a substance as either a liquid, solid, or vapor under conditions in which it is normally unstable in that state.
Or
A state of pseudo-equilibrium having higher free energy than the true equilibrium state.

Ergodicity
An attribute of stochastic systems; generally, a system that tends in probability to a limiting form that is independent of the initial conditions
Weak ergodicity breaking ("non-conventional ergodicity breaking" ~Bouchaud)
Never achieves a steady-state; forever evolving
True ergodicity breaking (Bouchaud):
The existence of many pure states between which infinite barriers stand

Prepared by Randy Ewoldt
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Spin glass
A disordered material exhibiting high magnetic frustration; frustration refers to the inability of the system to remain in a single lowest energy state (the ground state)

Activated dynamics
Glassy dynamics are often studied using hopping (trap) models, in which single particle degrees of freedom hop by an activated dynamics, in an uncorrelated manner, through a random free energy landscape
Material evolves due to randomized processes (e.g. thermally activated in the SGR model)

Aging (as defined in this article)
A system ages if at least one of its response functions violates Eq. 18, i.e. it ages if the long time response does not converge for $t_w \to \infty$ (all other deviations from TTI are transients)

Weak v. Strong long-term memory
For the SGR model, any long term memory is indeed weak…; we consider this an attractive feature
Weak: properties are age dependent, but not influenced by perturbations of finite duration that occurred in the distant past.
Strong: not weak; contrast to above

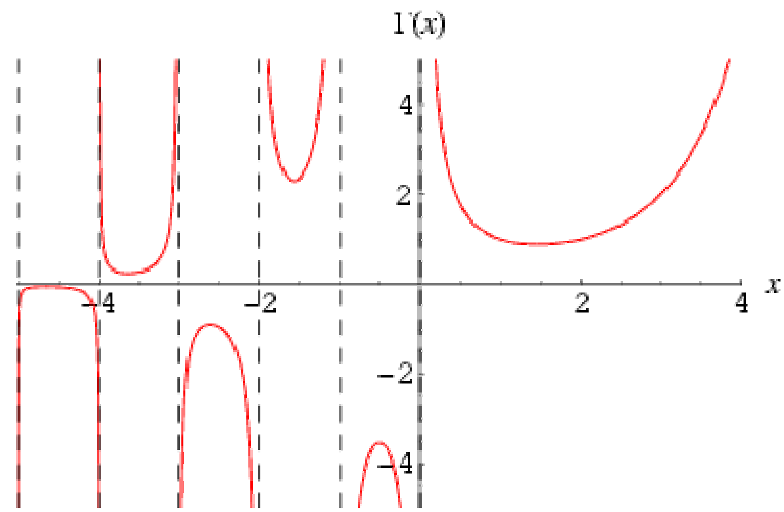
Yield
An element has a probability to yield, dependent on strain l and trap depth E, in which it rearranges to a new configuration of local equilibrium with $l = 0$

Noise induced yield: $\frac{1}{2}kl^2 \ll E$

Strain induced yield: $\frac{1}{2}kl^2 \approx E$

Gamma function
$\Gamma(x+1) = (x-1)!$

$\Gamma(x) = \int_0^\infty t^{x-1} e^{-t}\, dt$



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Abbreviations and Acronyms

SGM: soft glassy materials
SGR: soft glassy rheology (the model considered in this paper)
TTI: time translation invariance

Important Variables in SGR model

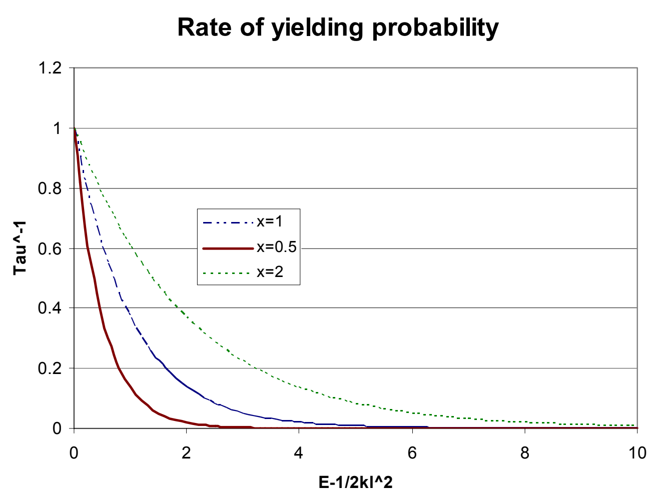
x : noise temperature, or effective temperature

x<1	glass phase, includes yield stress and aging behavior
1<x<2	transients but no aging
2<x	Newtonian regime

x may be non-zero even as $k_B T \to 0$, which is regarded as *uncertainty of its interpretation*

τ : effective relaxation time (yield time), or lifetime of a particle

$$\tau = \tau_0 \exp\left[(E - \tfrac{1}{2} kl^2) / x \right] \text{ (can still yield at } l = 0\text{)}$$



$Y = \langle \tau^{-1} \rangle$: rate of yielding

τ_0 : microscopic relaxation time (attempt time),
time to relax with zero energy barrier (E=0)

t_w : waiting time since sample prep

$Z(t,t')$: effective time interval;
$Z(t,t') \rightarrow t - t'$ in linear limit (small γ)

$\eta = \sigma_{ss} / \dot{\gamma}$: viscosity only defined at steady state stress (they never mention thixotropy!)

l : local strain of each element

k : spring constant of any energy well

kl : local stress of each element

$\langle kl \rangle$: macroscopic stress of sample

$\langle\rangle$: averaging over elements

l_y : yield strain; element rearranges to new configuration of local equilibrium with $l = 0$

$E = \tfrac{1}{2} k l_y^2$: yield energy; the energy barrier to overcome
E assigned according to probability distribution

$\rho(E)$: "prior" probability distribution of E

$$\rho(E) = \frac{1}{x_g} \exp\left[-E / x_g \right] \qquad \text{where } x_g = \langle E \rangle$$

Choose units such that

$$x_g = k = 1$$

$$\tau_0 = 1$$

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