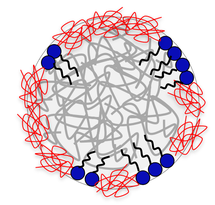
Study of irreversible strain hardening in *Hevea brasiliensis* latex gels

Guilherme de Oliveira Reis, Paul Menut, Laurent Vaysse, Fréderic Bonfils and Christian Sanchez

UMR IATE : UM2-CIRAD-INRA-SupAgro, Montpellier, France

Context

Natural rubber latex (NRL), extracted from *Hevea brasiliensis* tree, is a complex colloidal suspension mostly composed by rubber particles. These particles exhibit a core-shell structure in which a core composed of **poly(cis-1,4-isoprene)** chains is **surrounded by a mixed layer of proteins and phospholipids**. During processing, the suspension is coagulated by acidification, a process which results in the formation of a **colloidal gel**. In this study, we investigated the **rheological properties** of those gel **in a large range** of volume fraction (Φ_v = 0.01 to 0.5) **in the linear and non-linear regime**.

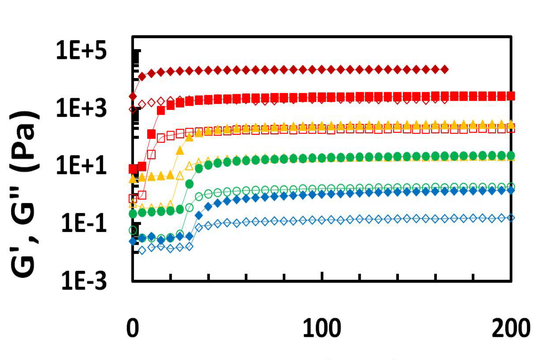


Materials & Methods

A prevulcanized NRL suspenions(DALBE) was acidified by addition of Glucono-δ-lactone, which hydrolysis allows a continuous, homogeneous acidification. Oscillatory measurements were performed using three different Couette geometry (smooth, serrated and PMMA) in a stress-imposed rheometer (TA Instruments AR200ex and ARG2). The **gel** was **formed *in situ*** during 4 hours (*time sweep test*, 0.5% and 1Hz), and then characterized through **continuous oscillatory stress increase** (1Hz) at 20° C.

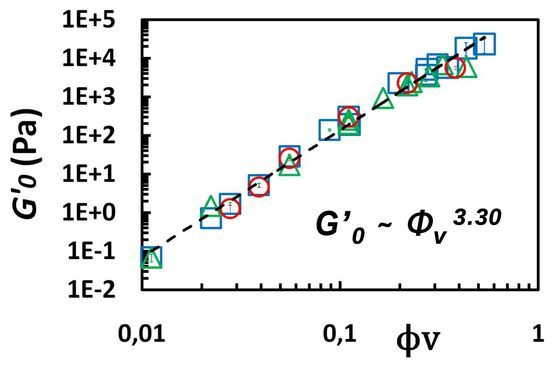
Linear regime

The destabilization of the suspension during acidification is associated with the formation of irreversible bonds (binding energy >> k_BT), and the emergence of **viscoelasticity** (G' and G").



G' G" function of time:

Φ_v = 0.4 , Φ_v = 0.2
Φ_v = 0.1 , Φ_v = 0.05 , Φ_v = 0.025



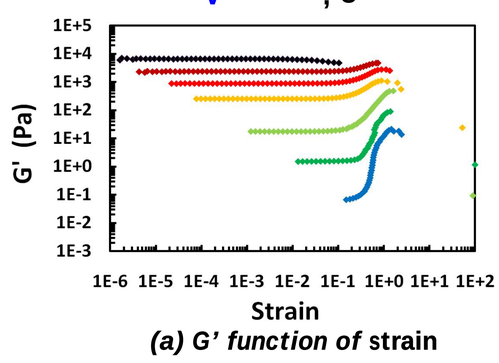
G'o function of volume fraction :

Blues squares: smooth Couette
Green triangles: serrated Couette
Red circles: PMMA Couette

NRL gel presented a **fractal** behavior **in the linear regime**

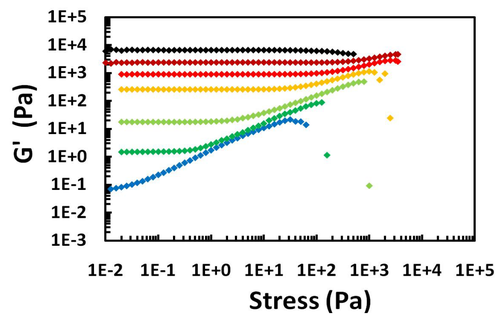
Non-linear regime

For $\Phi_v < 0.3$, gels showed a **strain hardening** behavior



(a) G' function of strain

for γ > **10%** both G' and G" increases with the strain, reach a maximum value G'_{max}, beyond which the gels fracture.



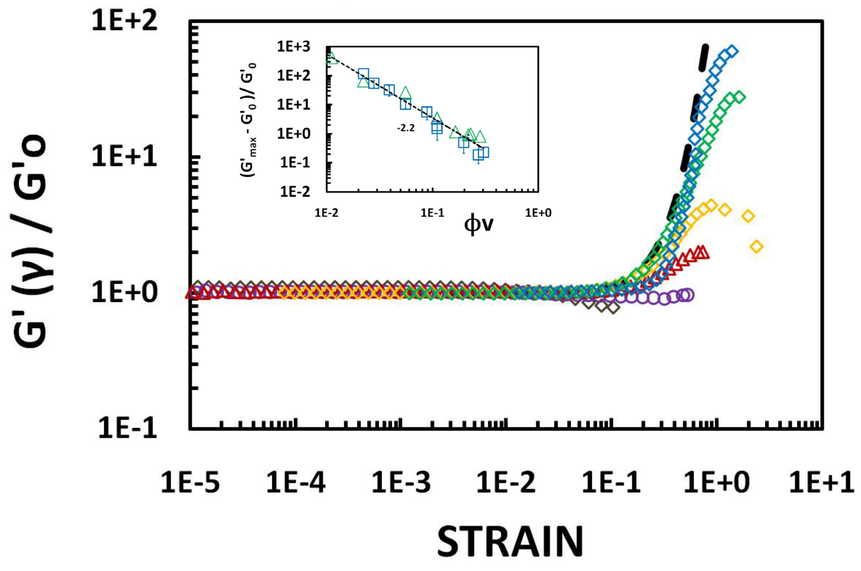
(b) G' function of stress

G' and G" increases almost linearly with the stress in the strain hardening regime.

Φ_v = 0.4 , Φ_v = 0.2 , Φ_v = 0.1 , Φ_v = 0.05 , Φ_v = 0.025

Strain hardening

The **relative amplitude** of the **strain hardening decreases** as the volume fraction increases till Φ_v = 0.3, above which hardening is not observed.

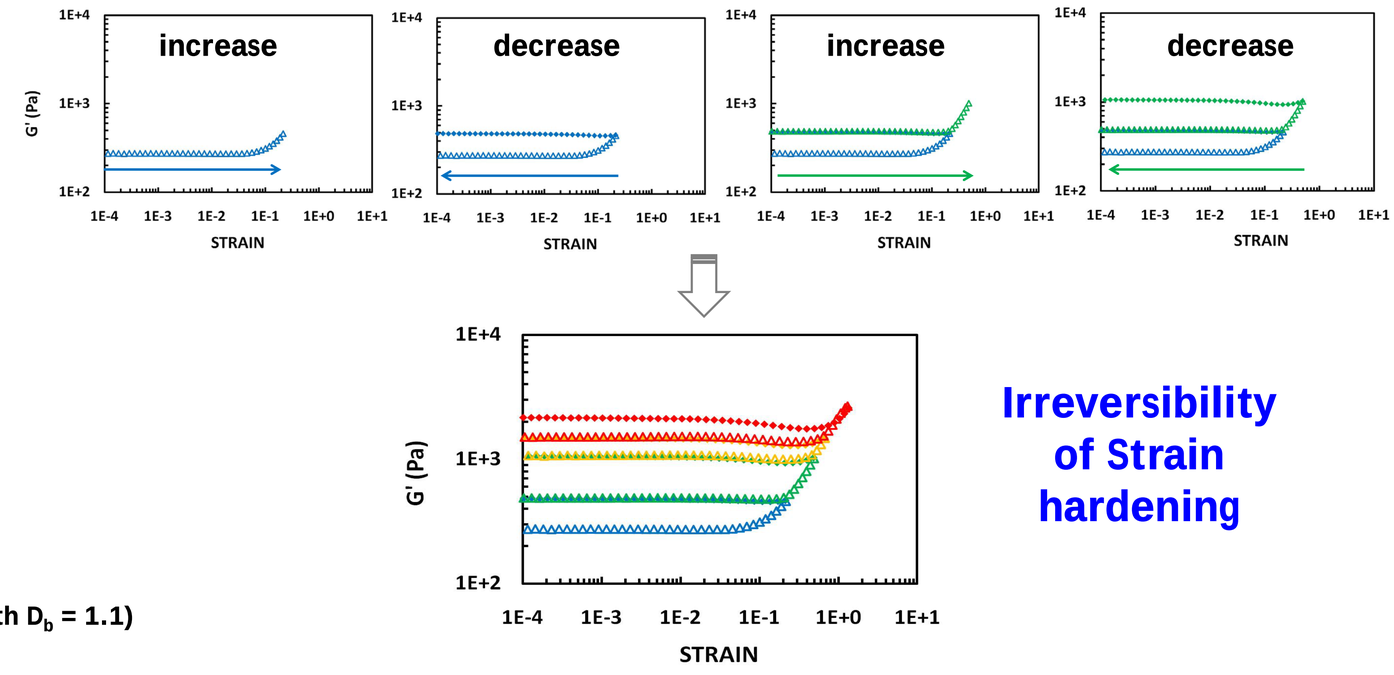


Strain hardening master curves function of Φ_v fitted by *Gisler et al.* [1] model (with D_b = 1.1)

Φ_v = 0.4 , Φ_v = 0.3 , Φ_v = 0.2 , Φ_v = 0.1 , Φ_v = 0.05 , Φ_v = 0.025

1 T.C. Gisler, R.C. Ball, D.A. Weitz, Phys. Rev. Lett. 82 (1999) 1064

The maximum value of **strain imposed during an oscillation was successively increased and decreased**.



Irreversibility of Strain hardening

G' function of strain: increases and decreases of strain Φ_v =0.1

Conclusions

Strain hardening behavior **starts around γ = 10%**

It does **not depend on Φ_v (master curve)**

Strain hardening **is irreversible, Its relative amplitude decreases with Φ_v**

We thank the Brazil's Science Without Borders Program from CNPq for supporting the PhD project

guilherme.de_oliveira_reis@cirad.fr