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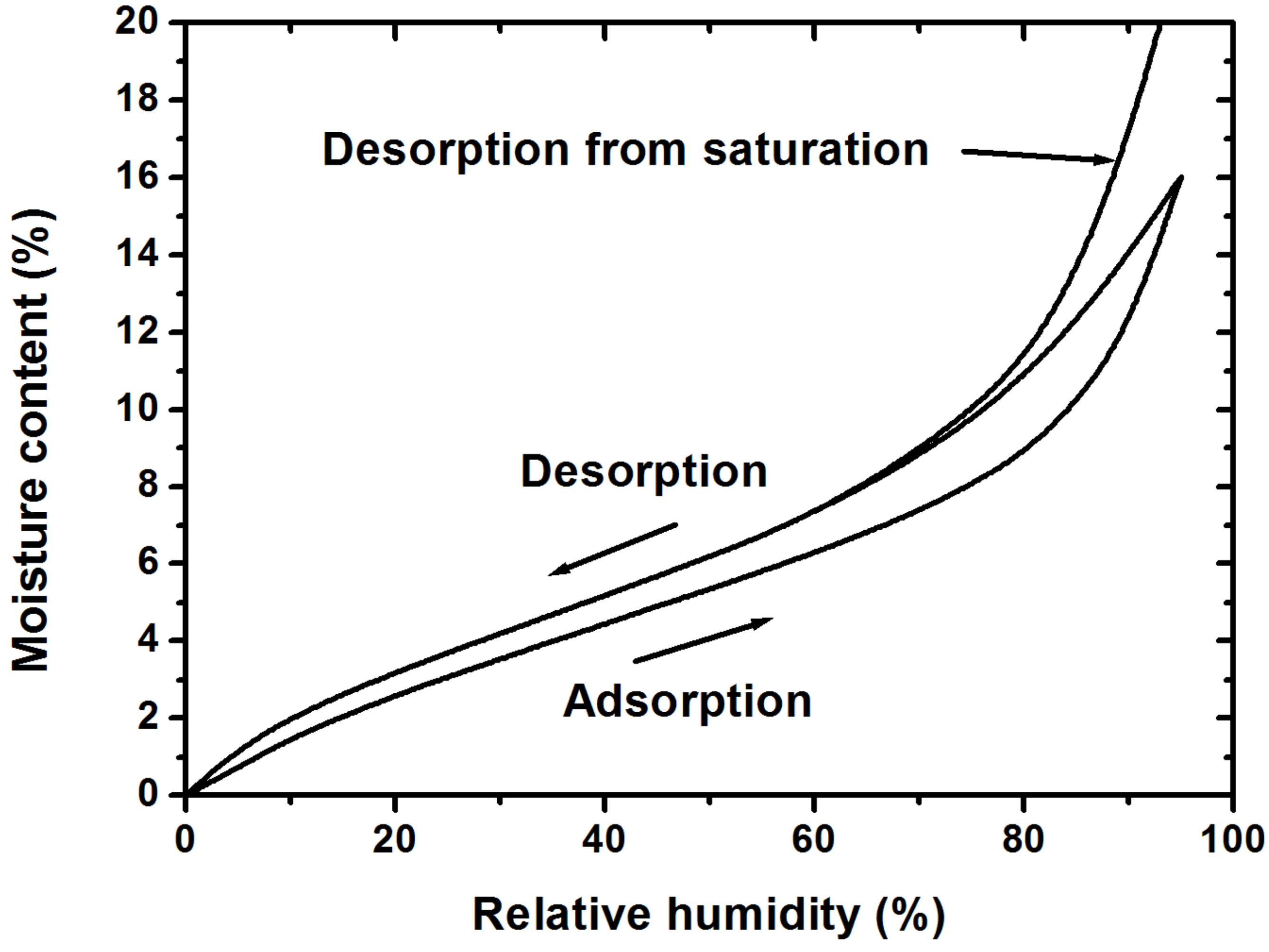
Water Vapour Sorption Kinetics

Professor Callum Hill

Edinburgh Research Partnership
Chair of Materials Science

HYSTERESIS



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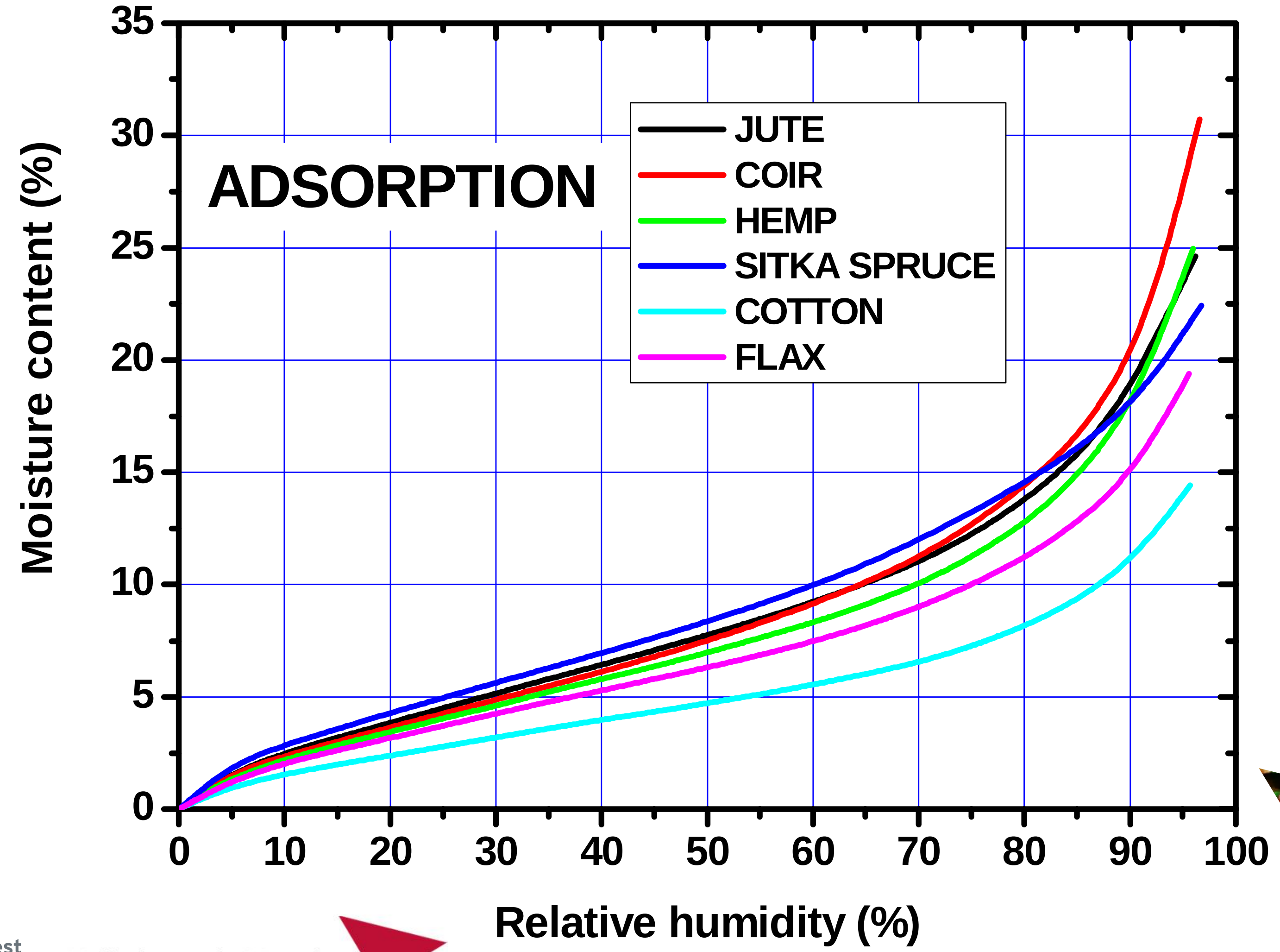

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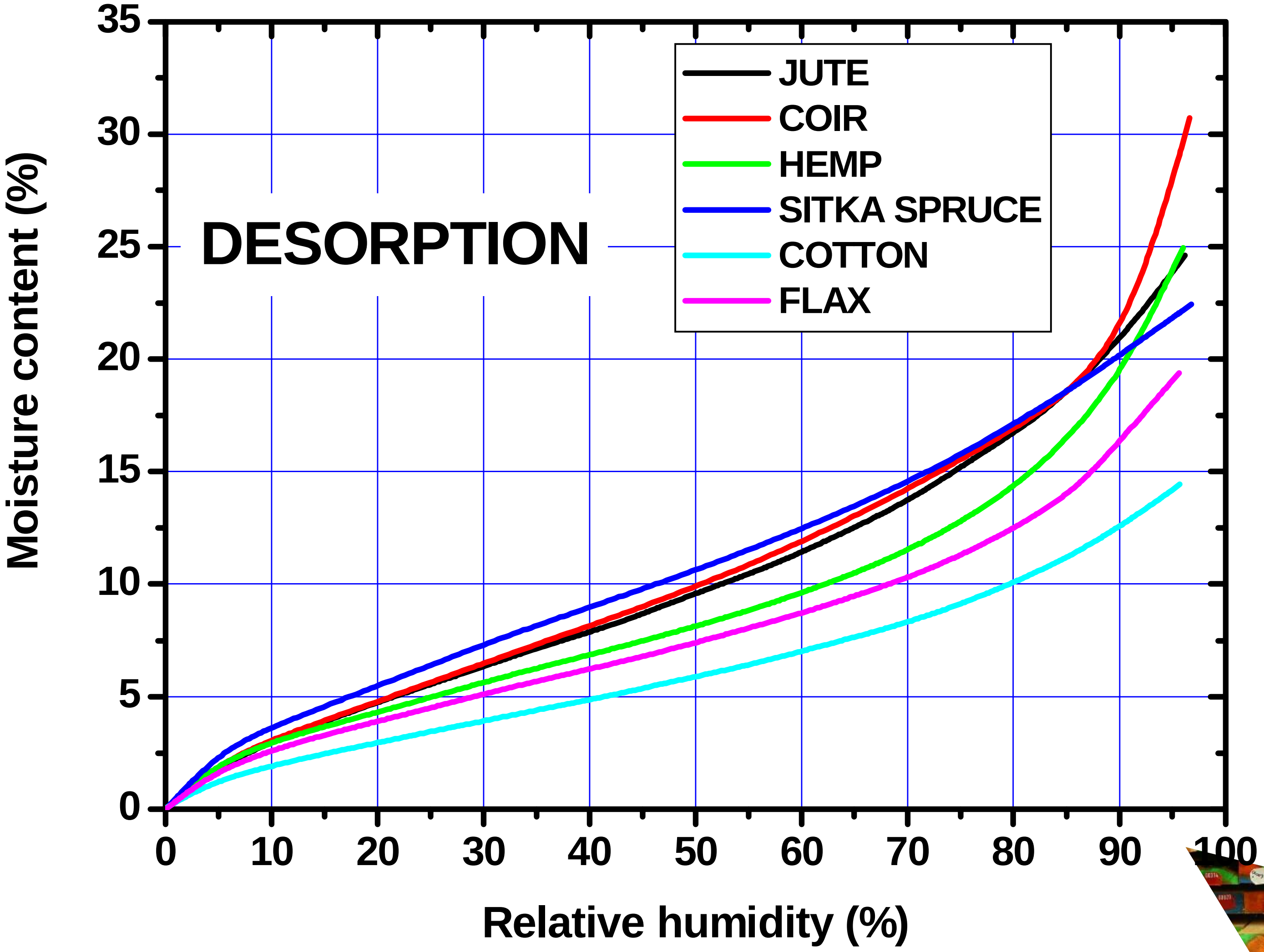

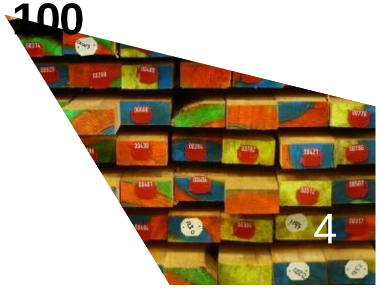

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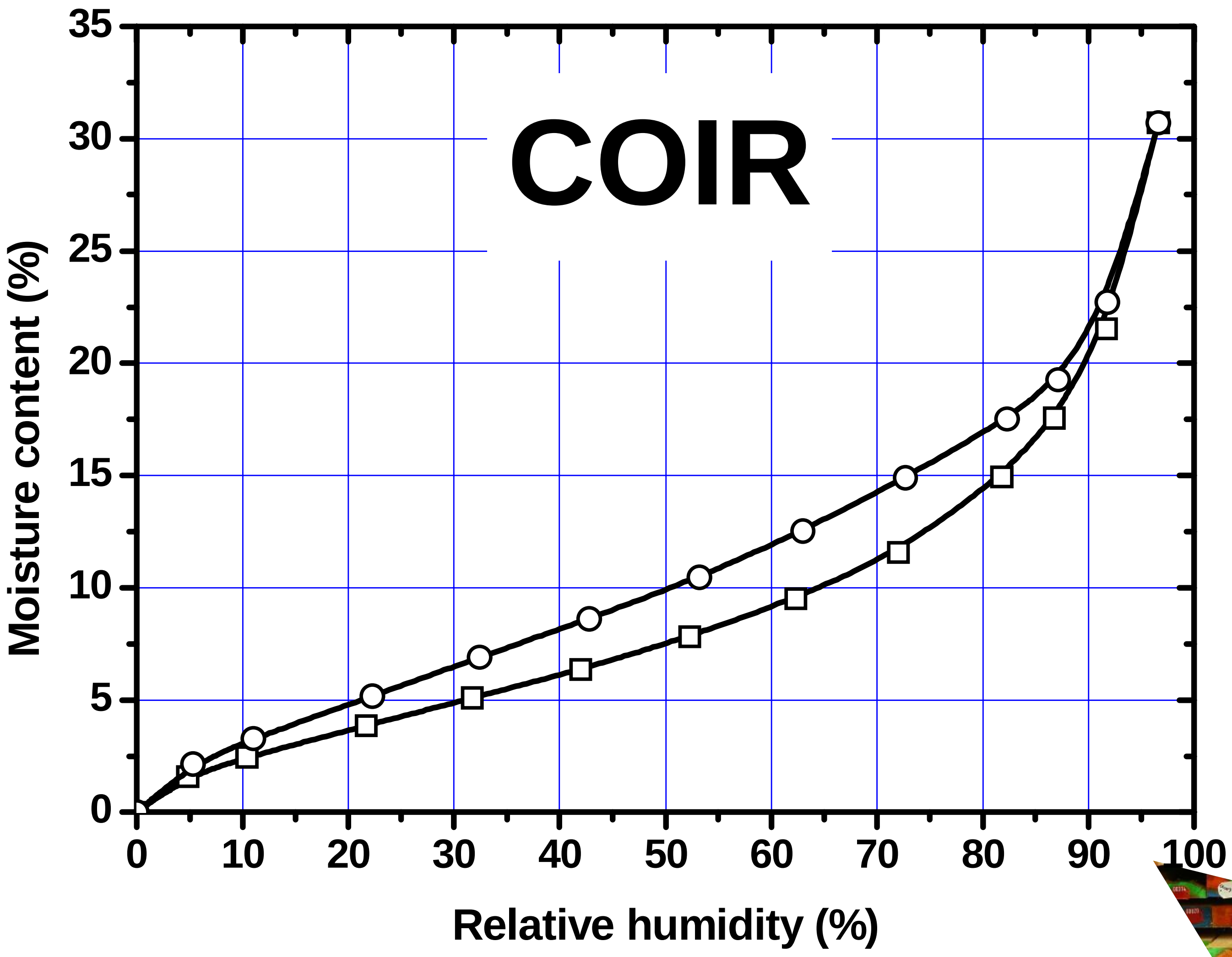

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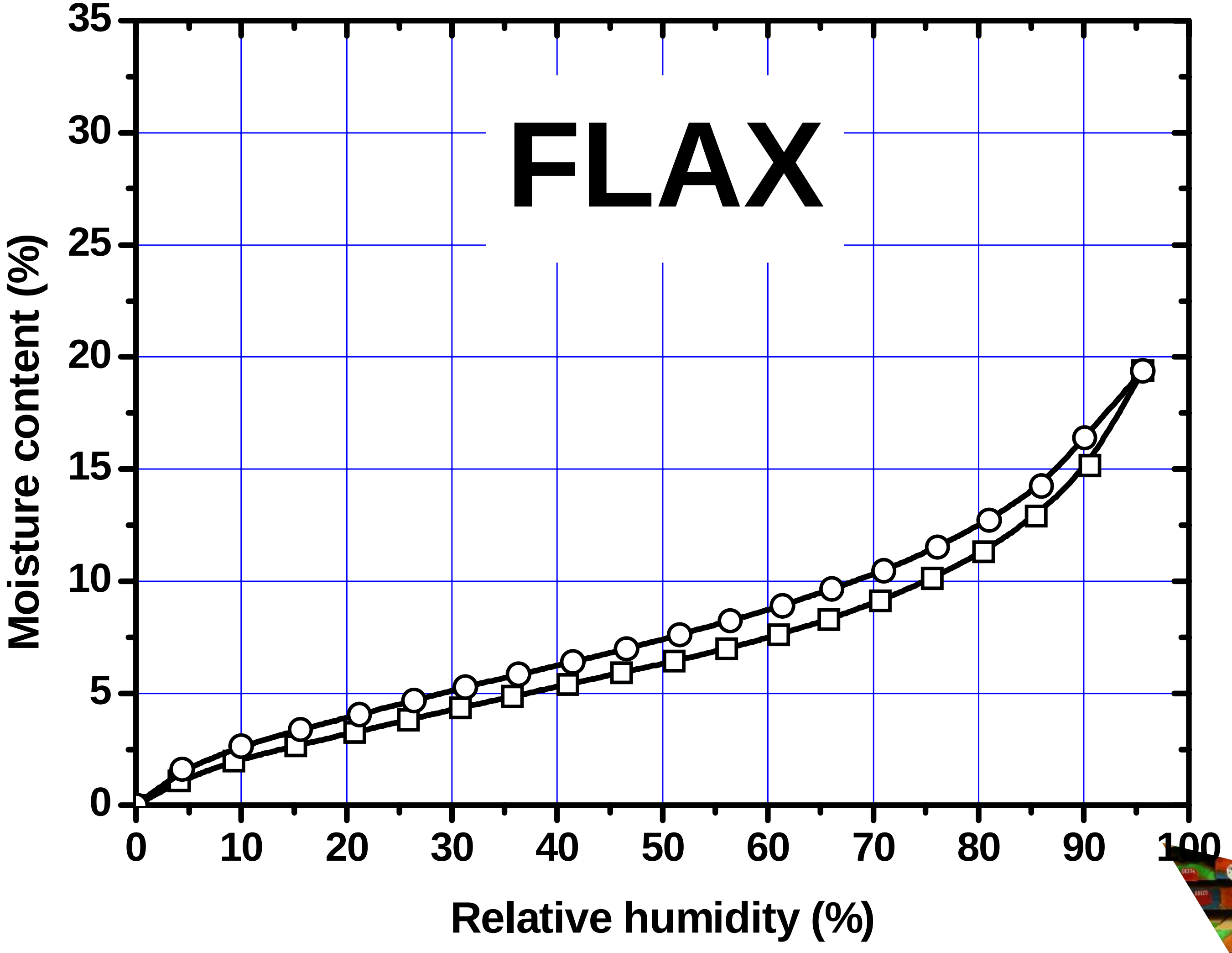
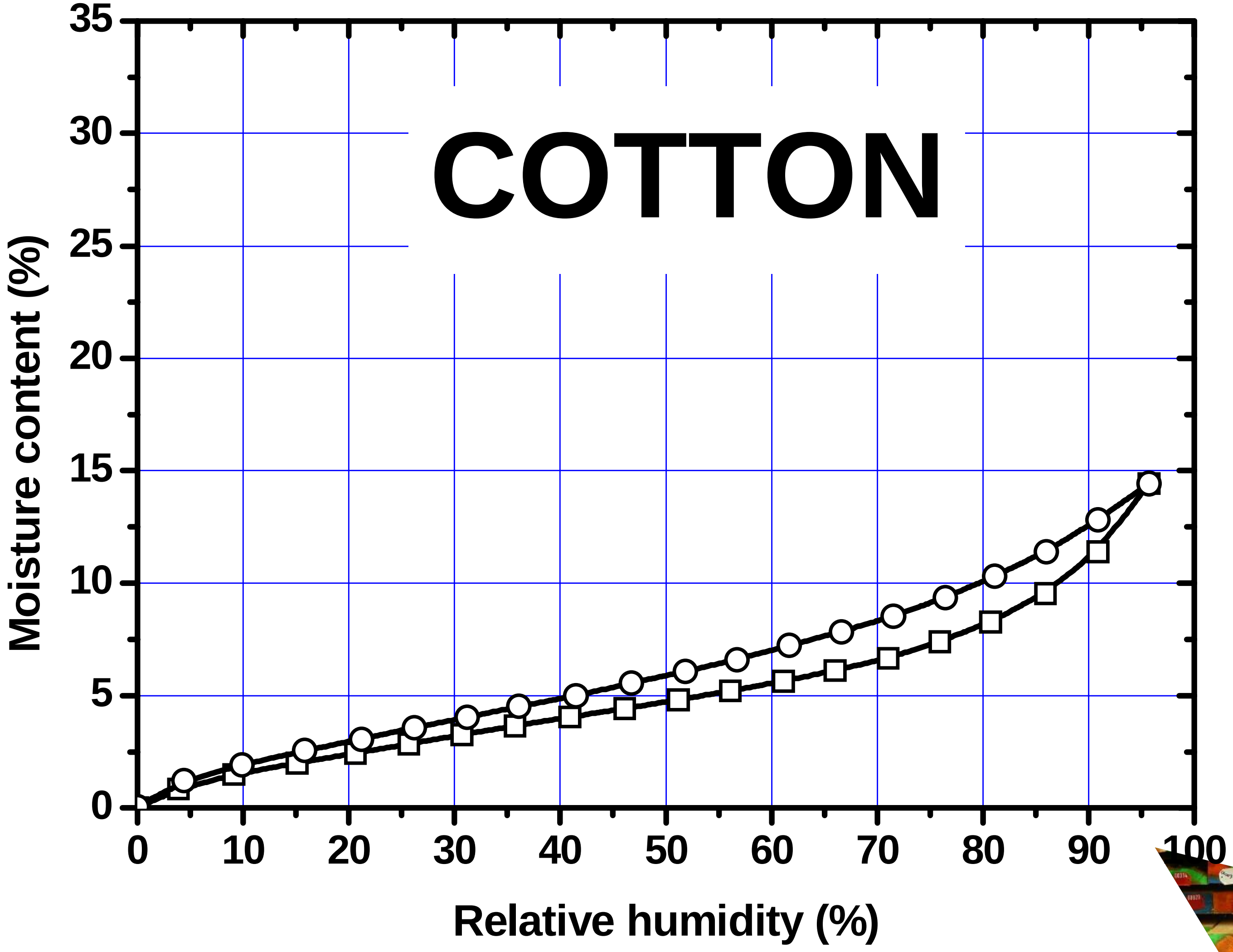


FLAX
Moisture content (%)
Relative humidity (%)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90
100



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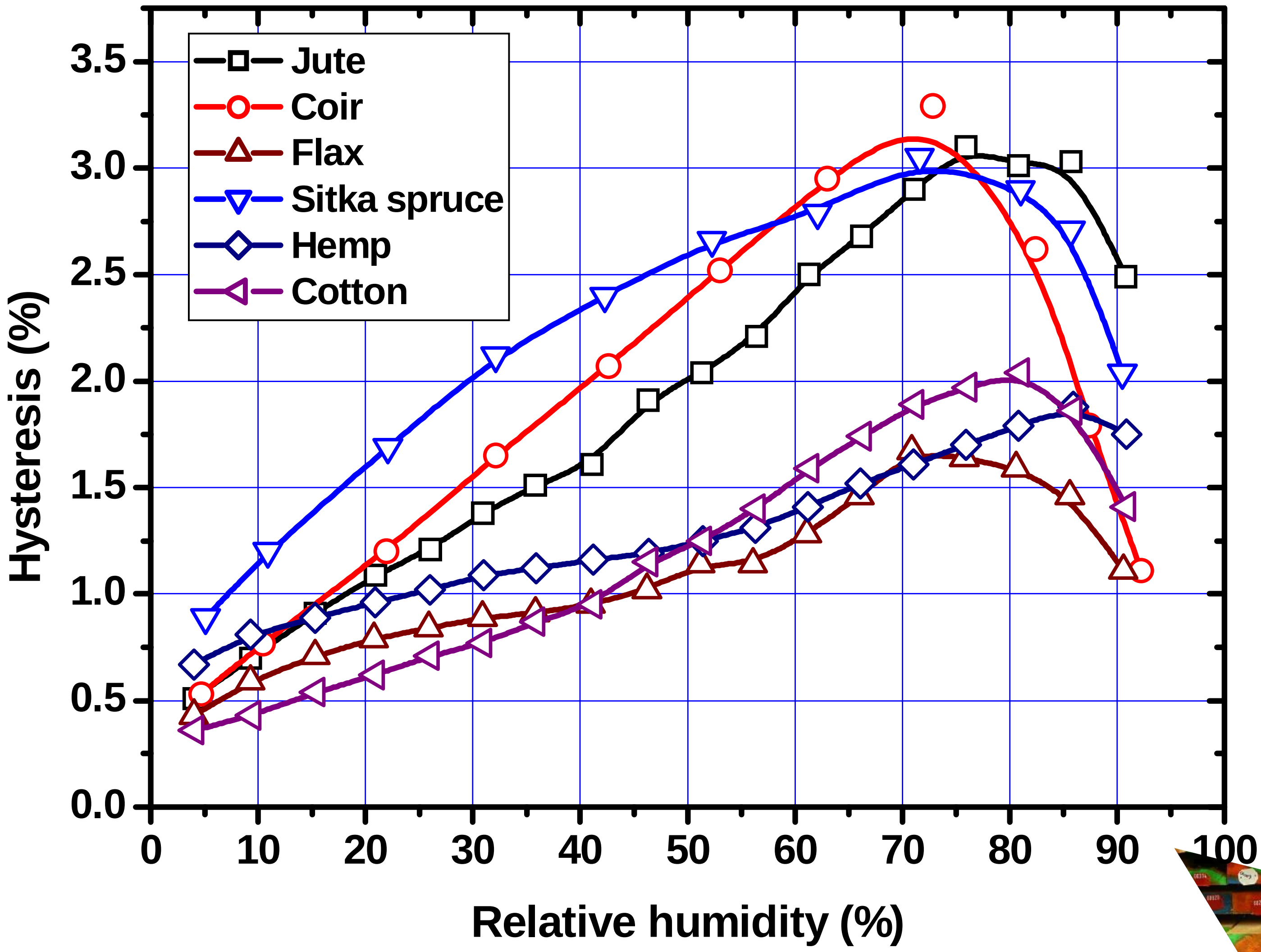
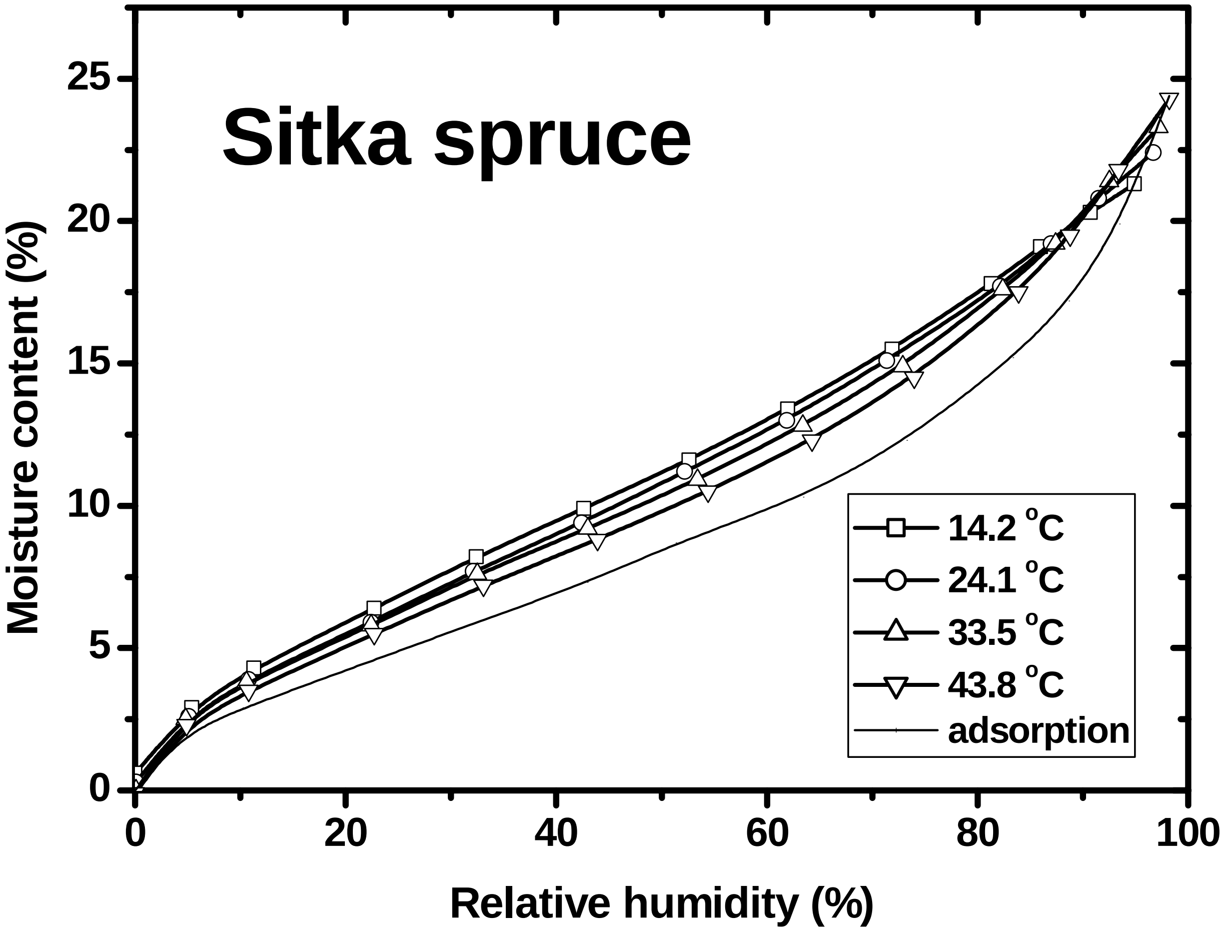


Jute
Coir
Flax
Sitka spruce
Hemp
Cotton
Hysteresis (%)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
10
20
30
40
50
60
70
80
90
100
Relative humidity (%)



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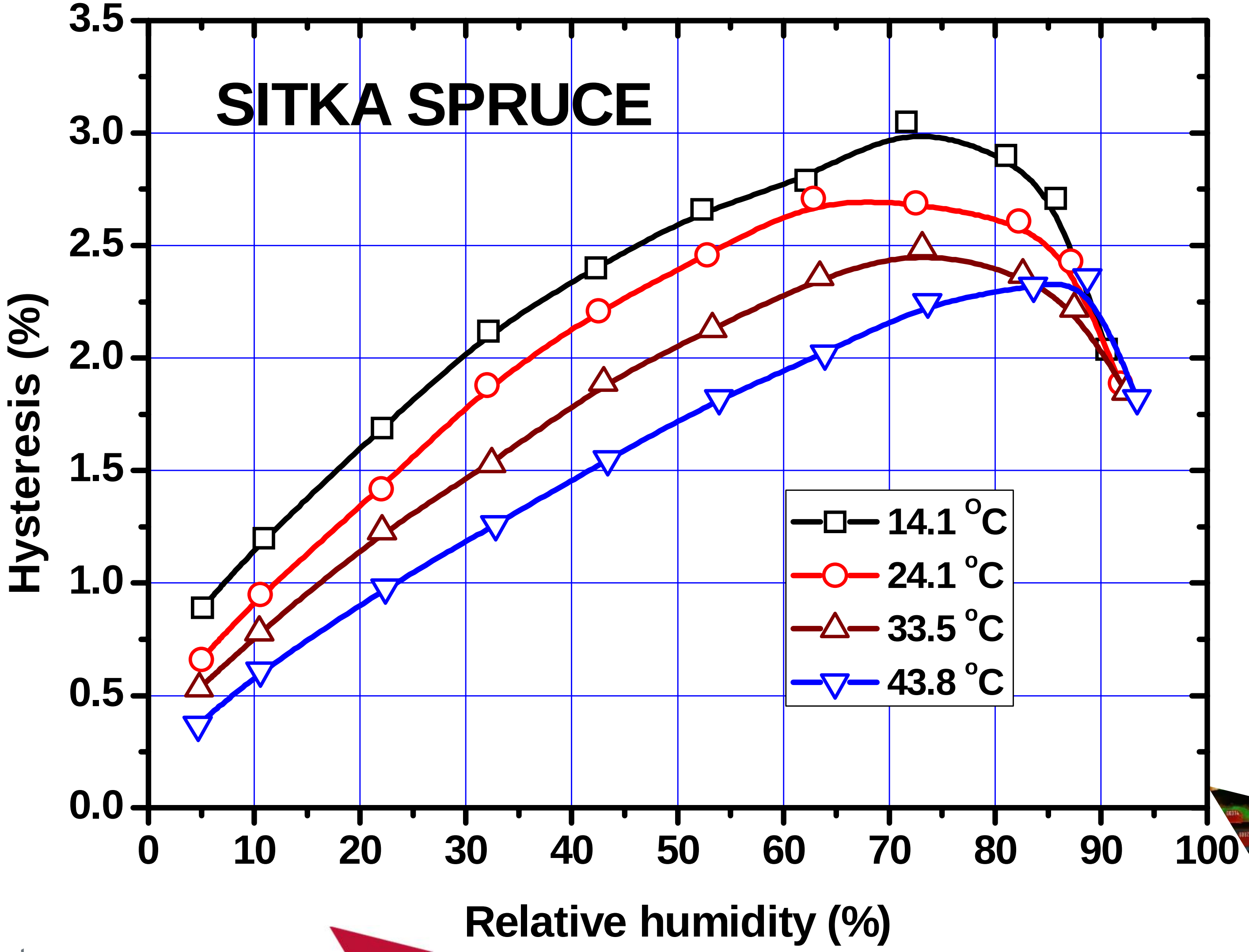

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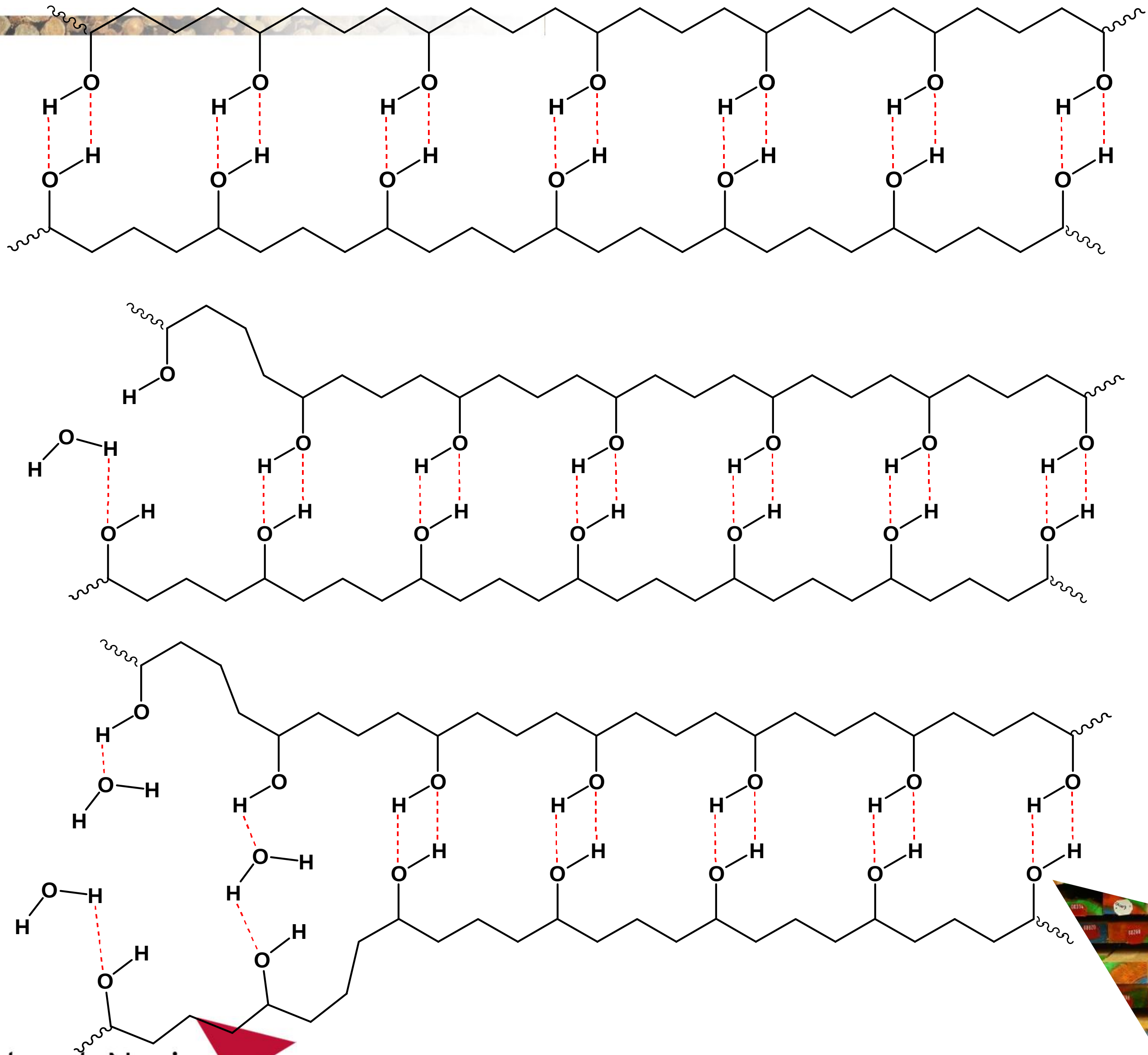
HYSTERESIS

- Sorption onto a glassy solid below the glass transition temperature
- At Tg hysteresis disappears
- Hysteresis arises due to adsorption and desorption into/out of a material in different states
- Matrix relaxation is the reason for this



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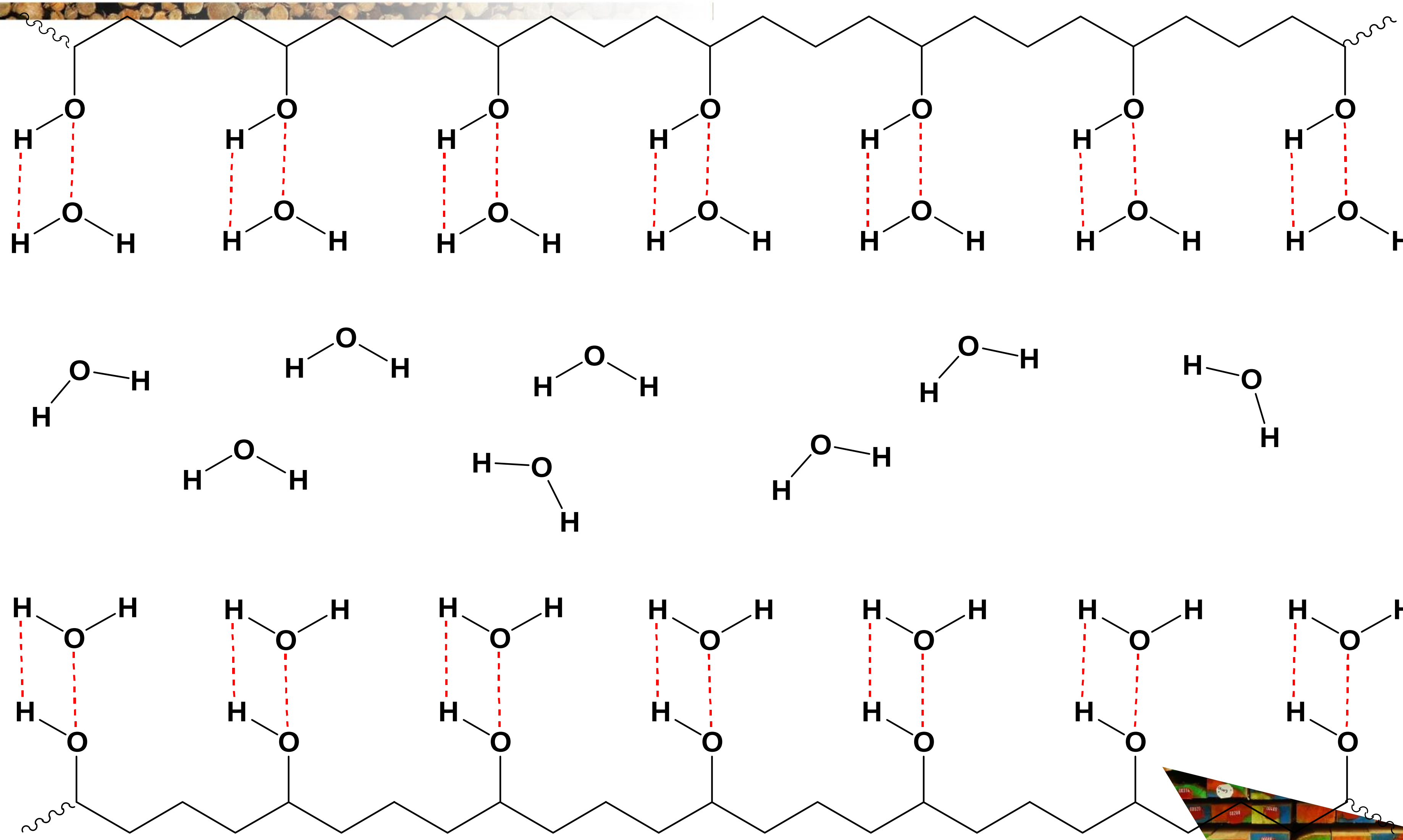
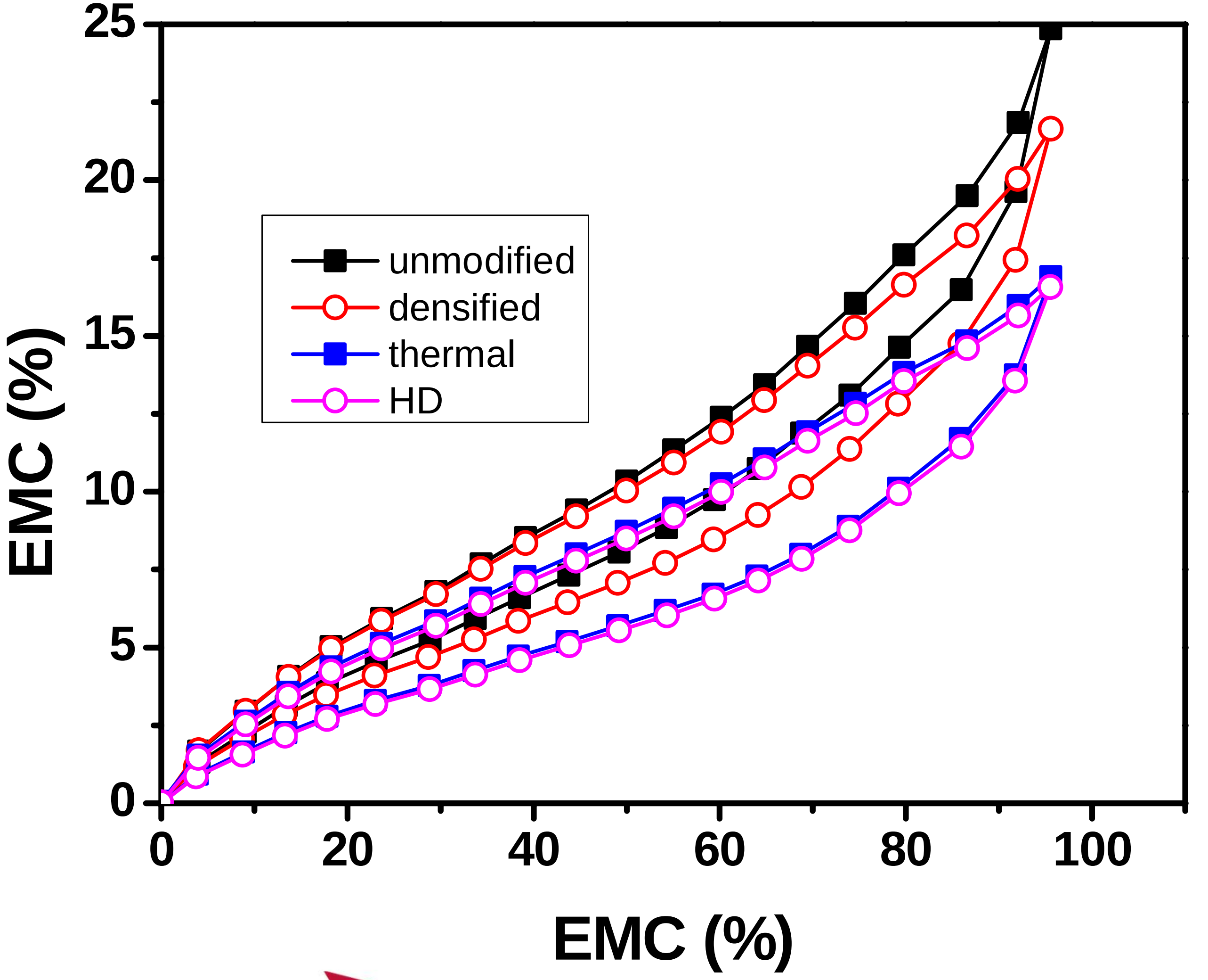


Study

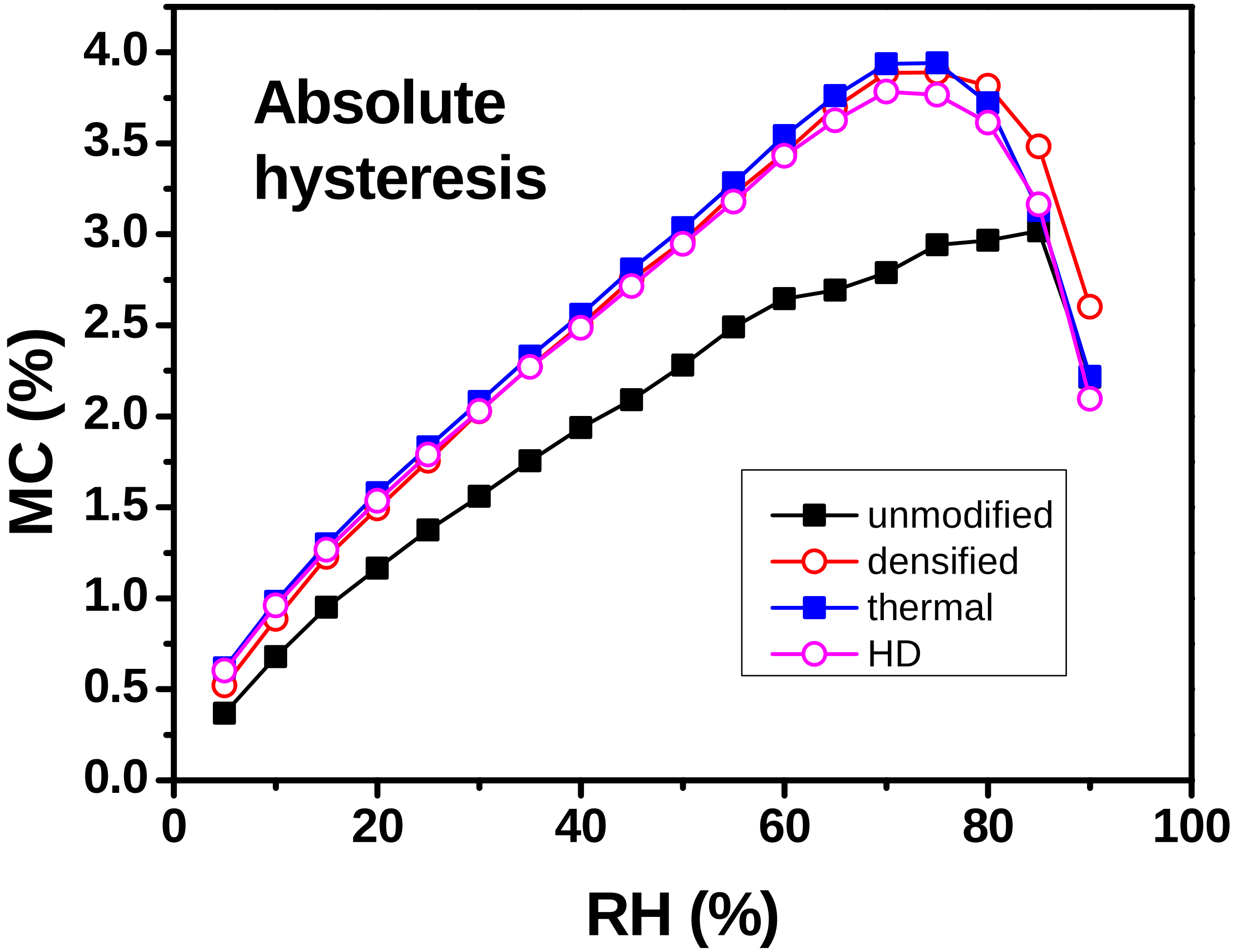
- Scots pine
- (1) Unmodified
- (2) Densified using 6 Mpa open press 150^{o}C steam
- (3) Thermal modification – 200^{o}C with injected steam for 2h
- (4) Densified and thermally modified

Isotherms



25
20
15
10
5
0
EMC (%)
0
20
40
60
80
100
EMC (%)
unmodified
densified
thermal
HD

Hysteresis



Absolute hysteresis
MC (%)
RH (%)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
20
40
60
80
100
unmodified
densified
thermal
HD

SORPTION KINETICS

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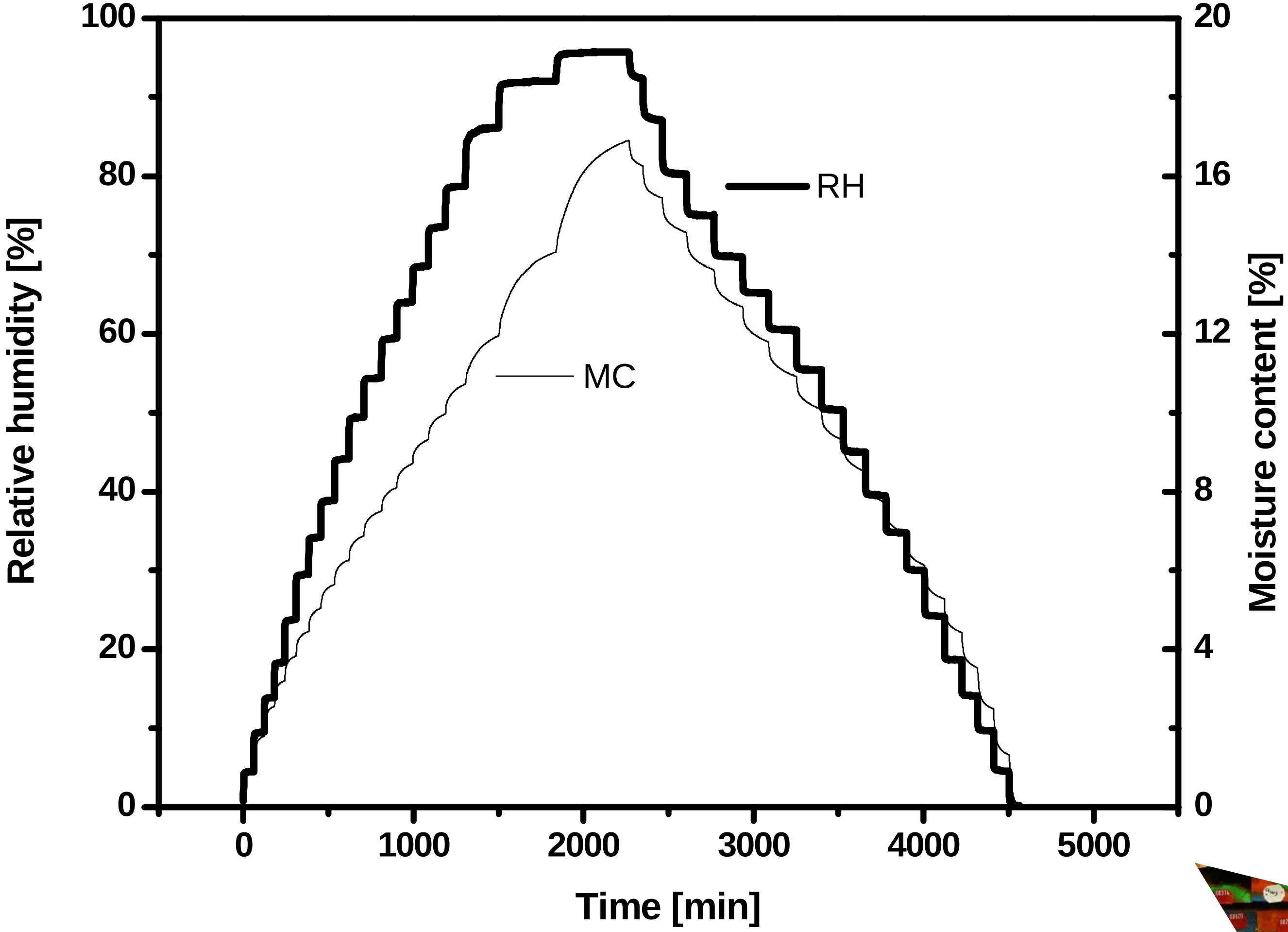
DVS RUN



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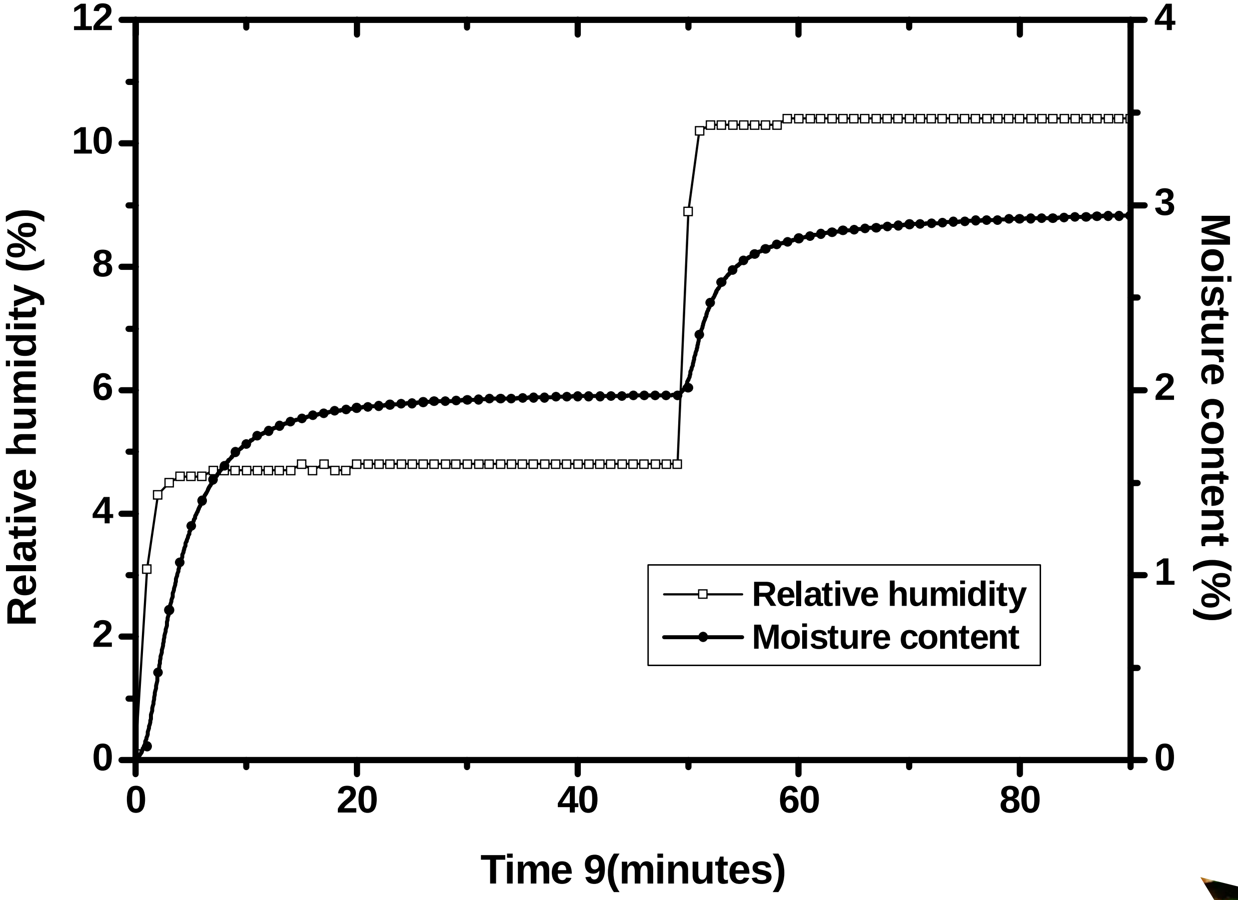
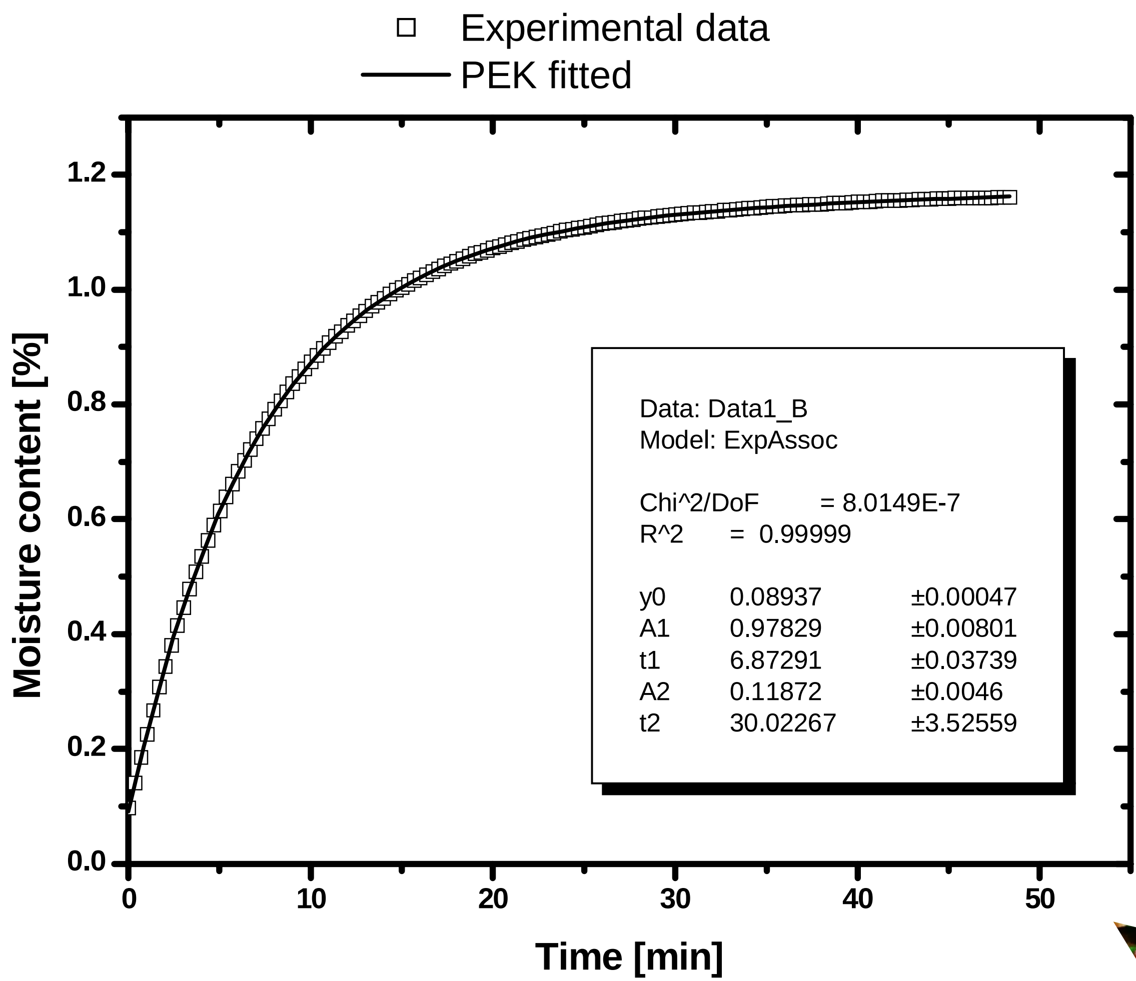


12
10
8
6
4
2
0
Relative humidity (%)
4
3
2
1
0
Moisture content (%)
0
20
40
60
80
Time 9(minutes)
Relative humidity
Moisture content

SORPTION KINETICS



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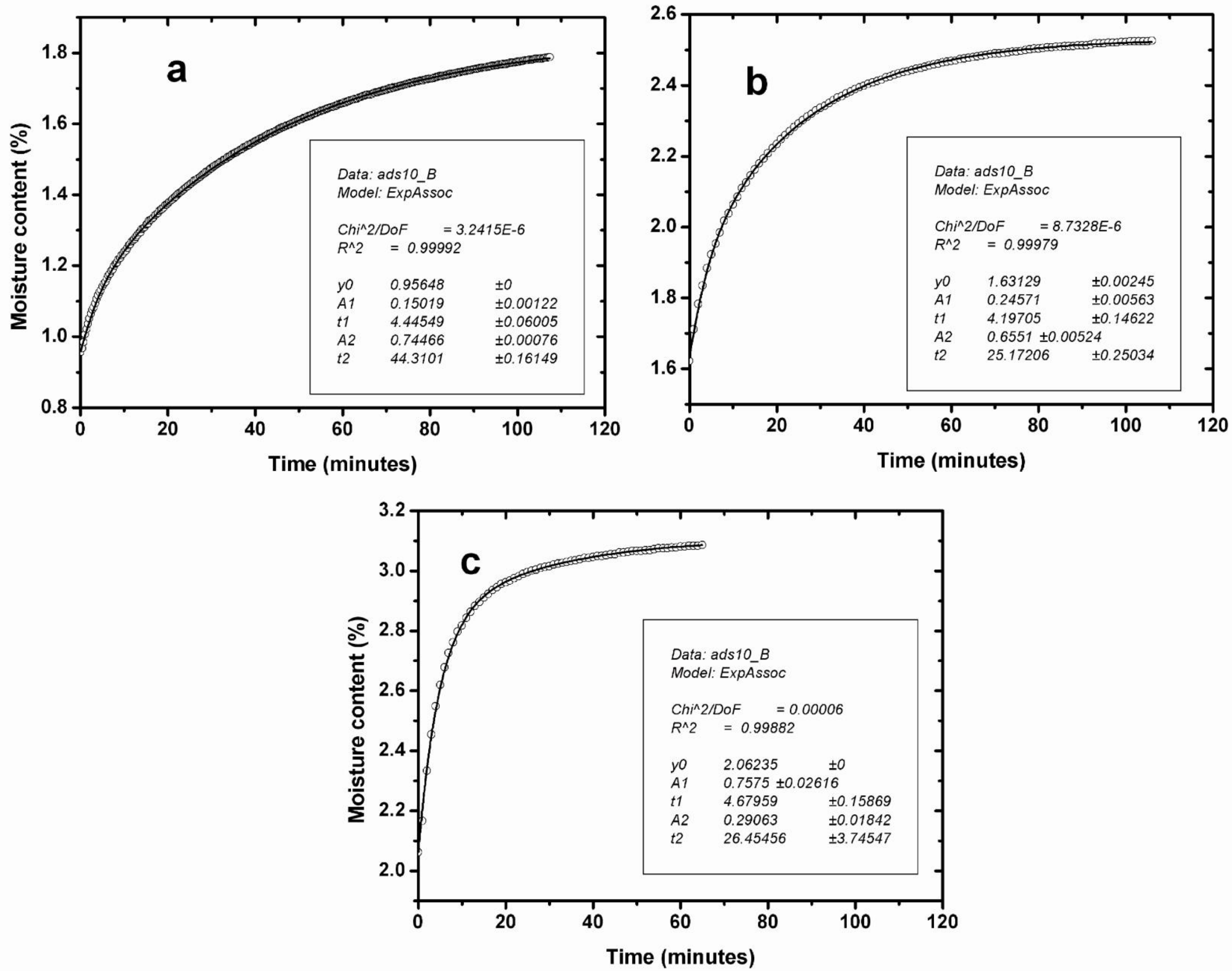

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PEK MODEL

- $MC = MC_0 + MC_1(1 - e^{-t/t_1}) + MC_2(1 - e^{-t/t_2})$

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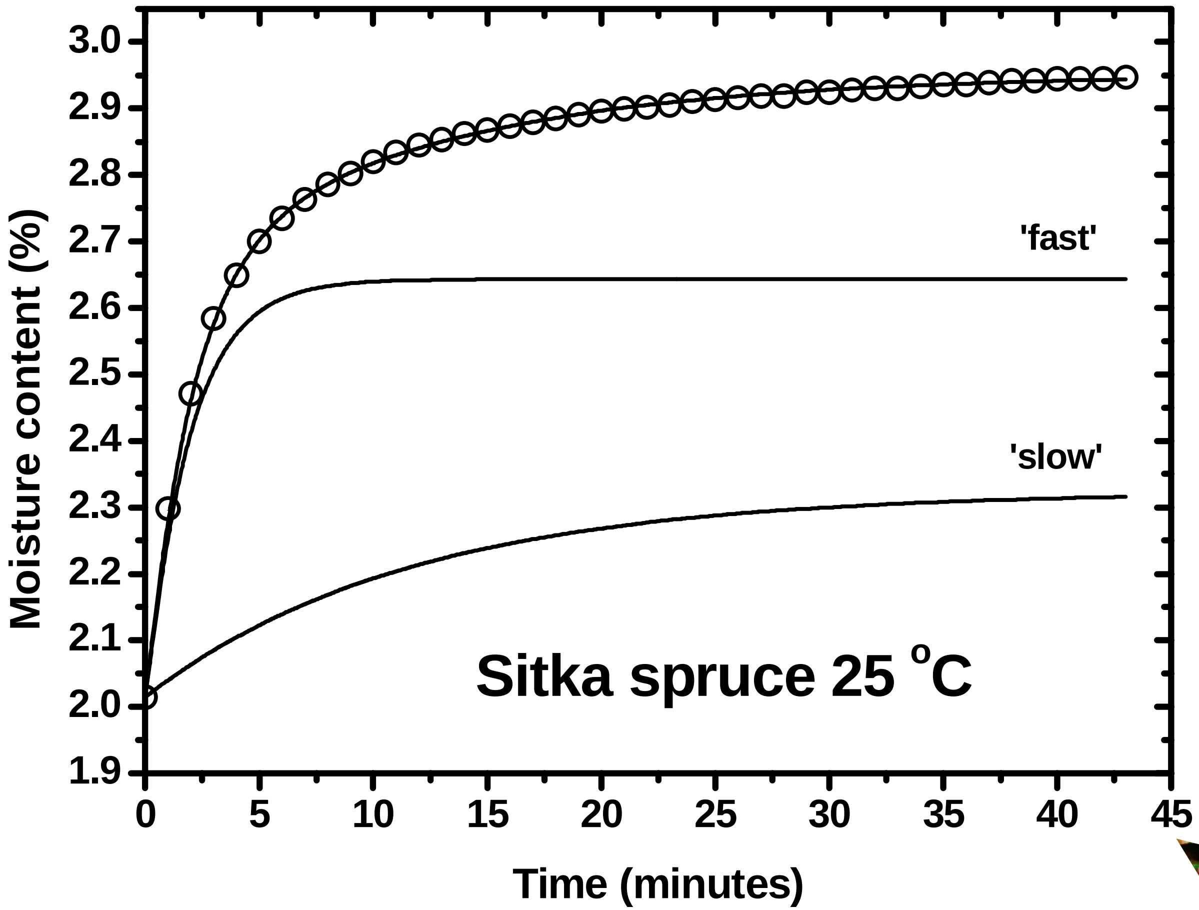
PEK MODEL



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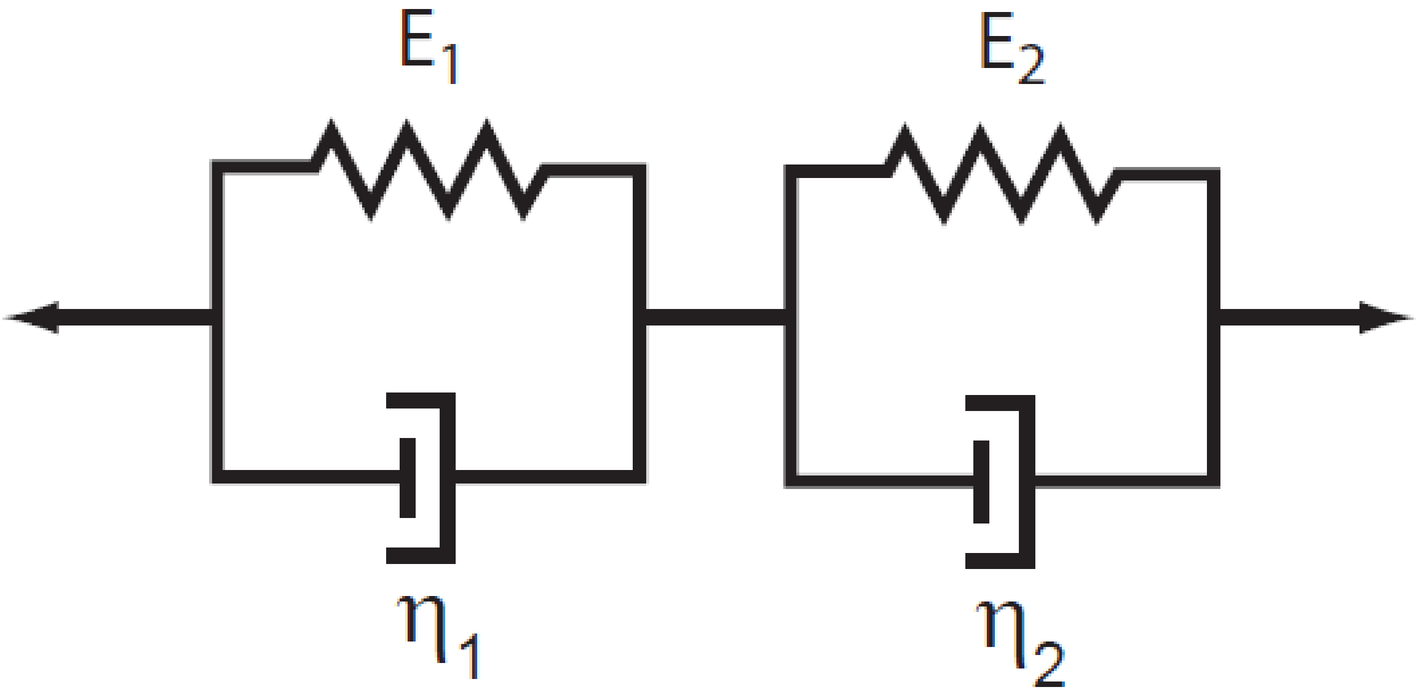
KELVIN-VOIGT

- Mechanical interpretation using Kelvin-Voigt viscoelastic model
- Rate limiting step of sorption process is polymer relaxation

KELVIN-VOIGT MODEL



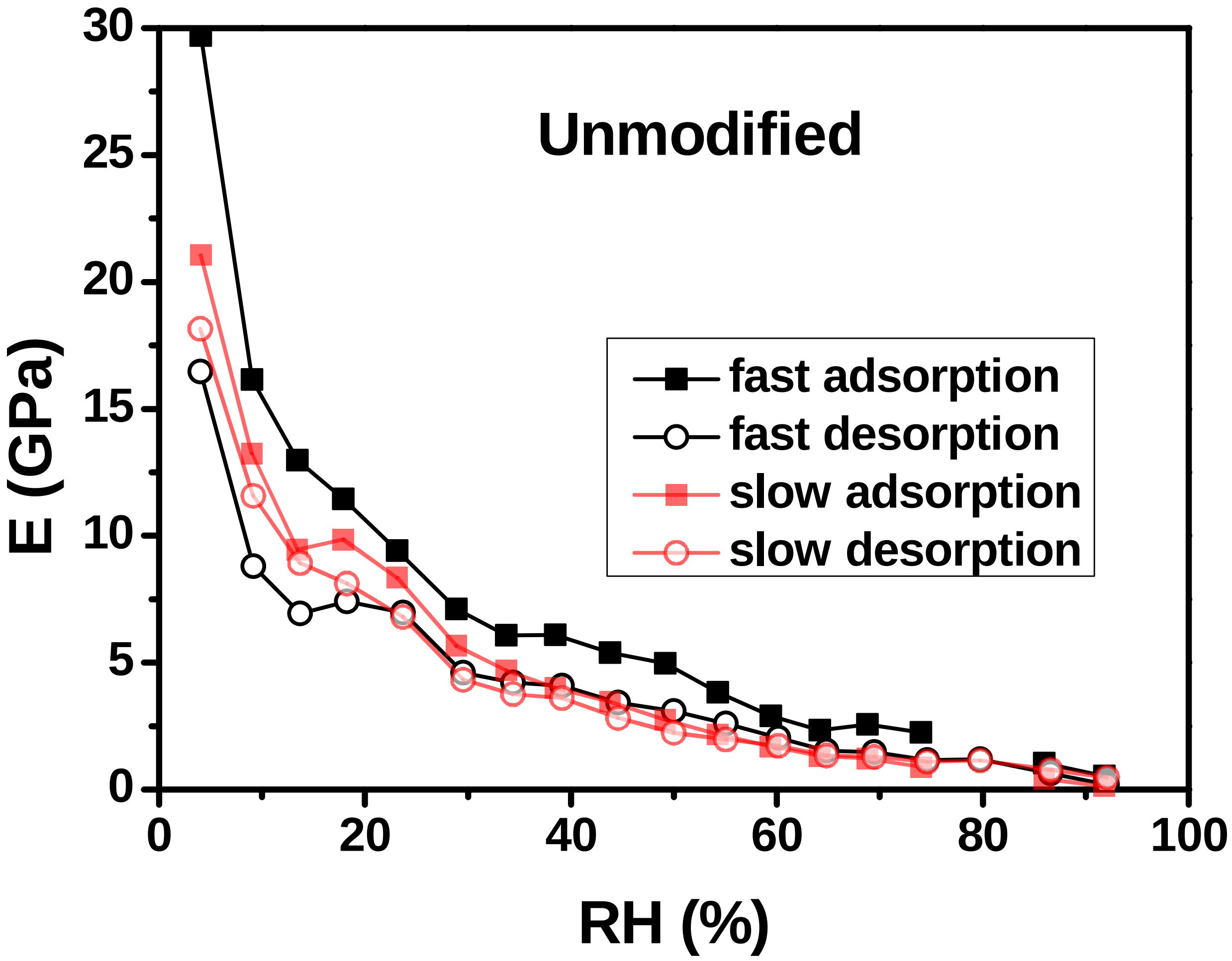
$$\varepsilon = (\sigma_0 / E)[1 - \exp(-t/\varphi)]$$

$$\varepsilon = (\sigma_0 / E)[1 - \exp(-t/\varphi)]$$

$$MC = MC_0 + MC_1(1 - e^{-t/t_1}) + MC_2(1 - e^{-t/t_2})$$

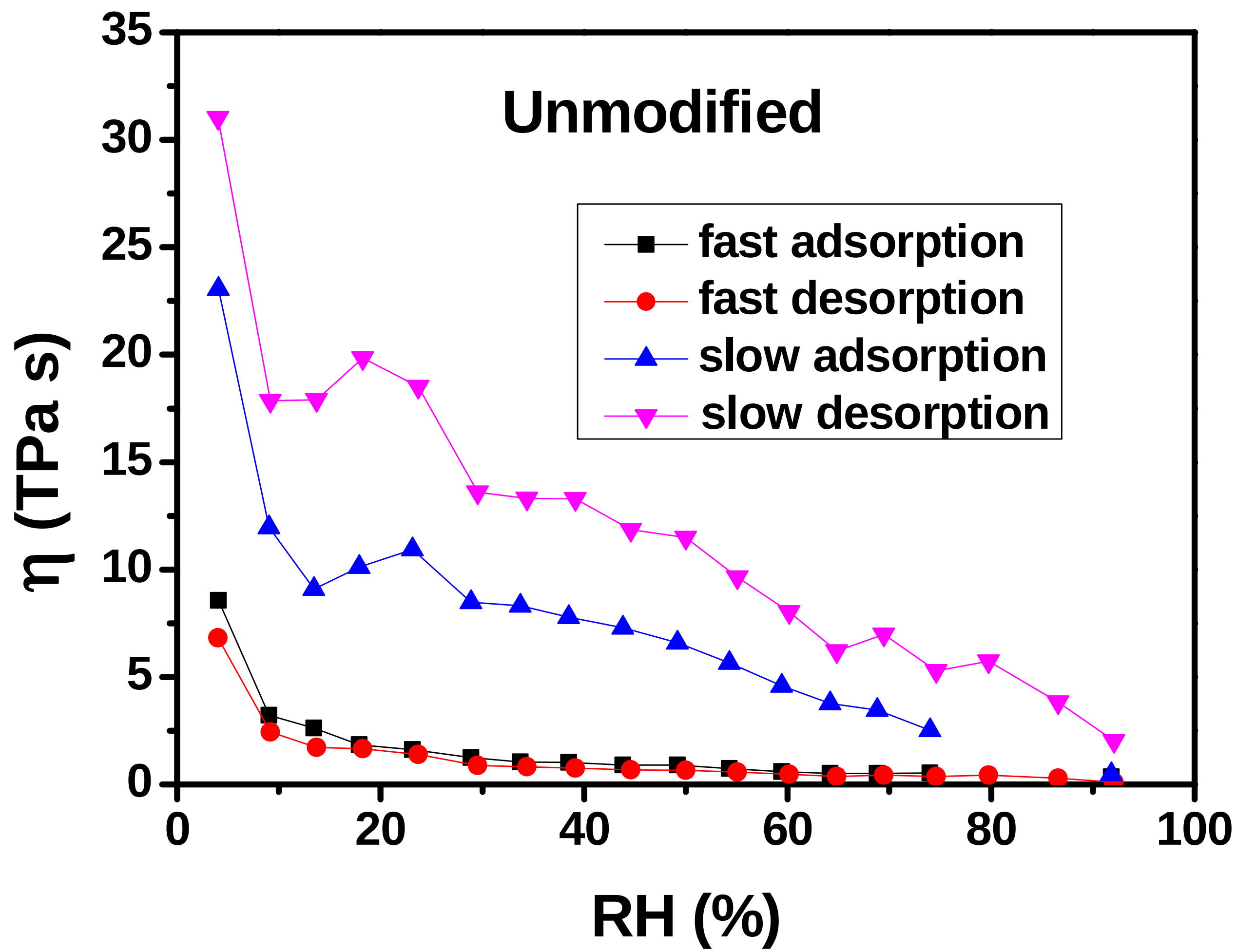
$$\sigma_0 \equiv \Pi = -(\rho/M)RT.\ln(p_i/p_f)$$

Modulus



Unmodified
E (GPa)
RH (%)
fast adsorption
fast desorption
slow adsorption
slow desorption
0
5
10
15
20
25
30
0
20
40
60
80
100

Viscosity



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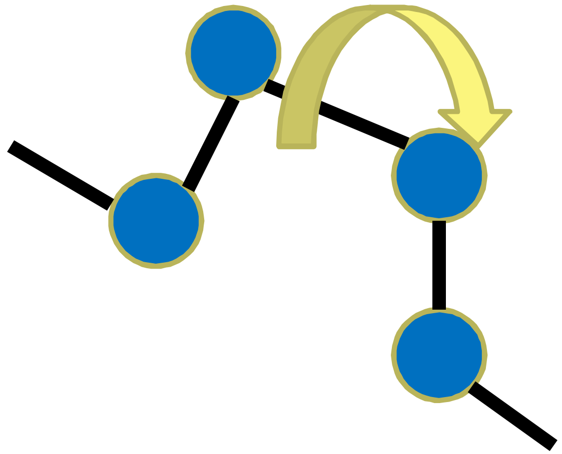
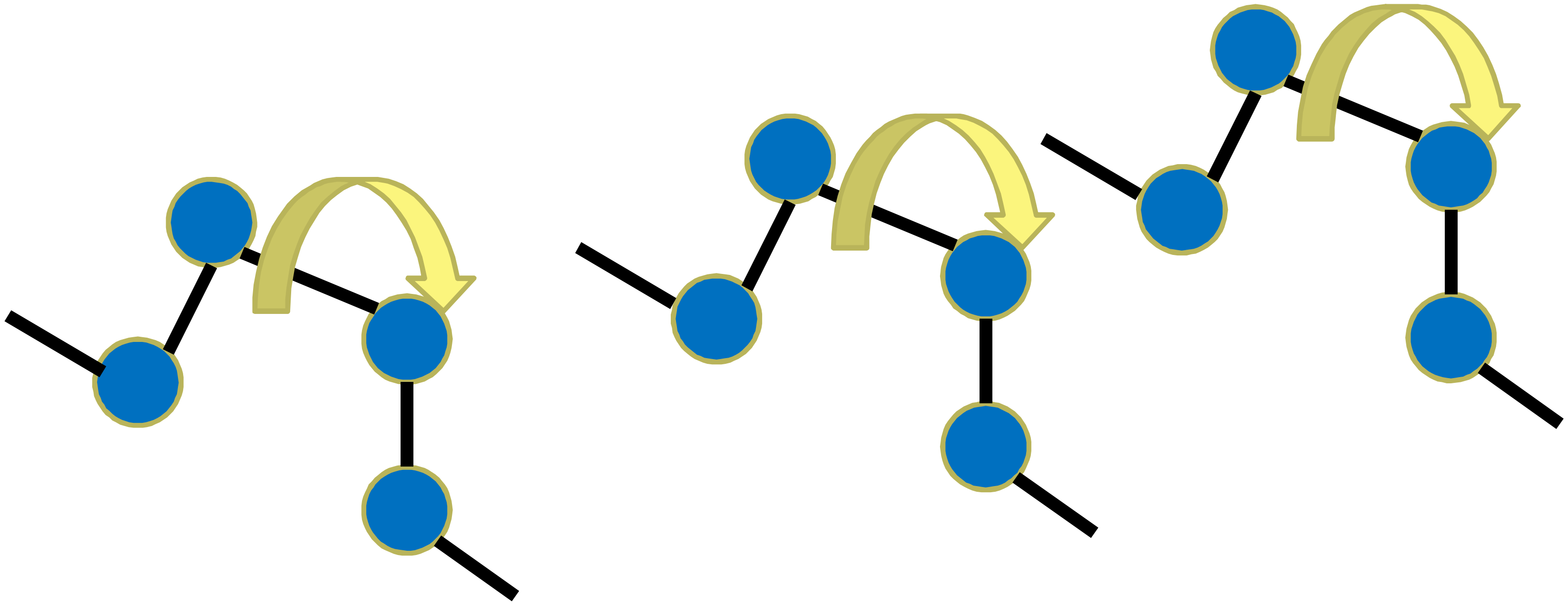
Cooperative Relaxation Processes in Polymers

J. Appl. Polym. Sci., 64, 77, (1997)

SHIRO MATSUOKA,[1] ARTURO HALE[2]





CONCLUSIONS

- A ‘mechanical’ interpretation gives results that are reasonable
- Need an independent way of determining the polymer relaxation characteristic times
- Fast = reinforcement? slow = matrix?

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