The interactions between lignocellulosics and water at a micro-level

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The ISOBIO project

Title: Development and Demonstration of Highly Insulating, Construction Materials from Bio-derived Aggregates

- Duration: 4 years (February 2015 – January 2019)
- Coordinated by TWI Ltd (Cambridge, UK)
- Budget of budget of 6,3M€
- Funded by the Horizon 2020 programme under a specific call to improve energy performance and reduced embodied energy across the whole life cycle of a building (EeB-01 - Materials for building envelope).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°636835.

Objectives

- To develop and bring new bio-based insulation panels and renders into mainstream in order to improve the energy efficiency of buildings;
- To assess and advance the state-of-the-art in natural insulation materials, and hygrothermally (heat and moisture) efficient buffering materials, binders, sol-gels and resins;
- To deliver products with at least:
  - **50% reduction in embodied energy and CO_2** emissions at component level;
  - **20% better insulation** properties than conventional materials;
  - **15%, lower construction costs**; and
  - **5% reduction in the total energy spent** over the lifetime of a building.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°636835.

The consortium

Multidisciplinary consortium of 11 partners from 6 different European countries.

TWI

acciona Infraestructuras

CAVAC Biomatériaux

CLAYTEC® Baustoffe aus Lehm.

Greenovate! EUROPE

modcell® straw technology

skog + landskap

PROGETIC

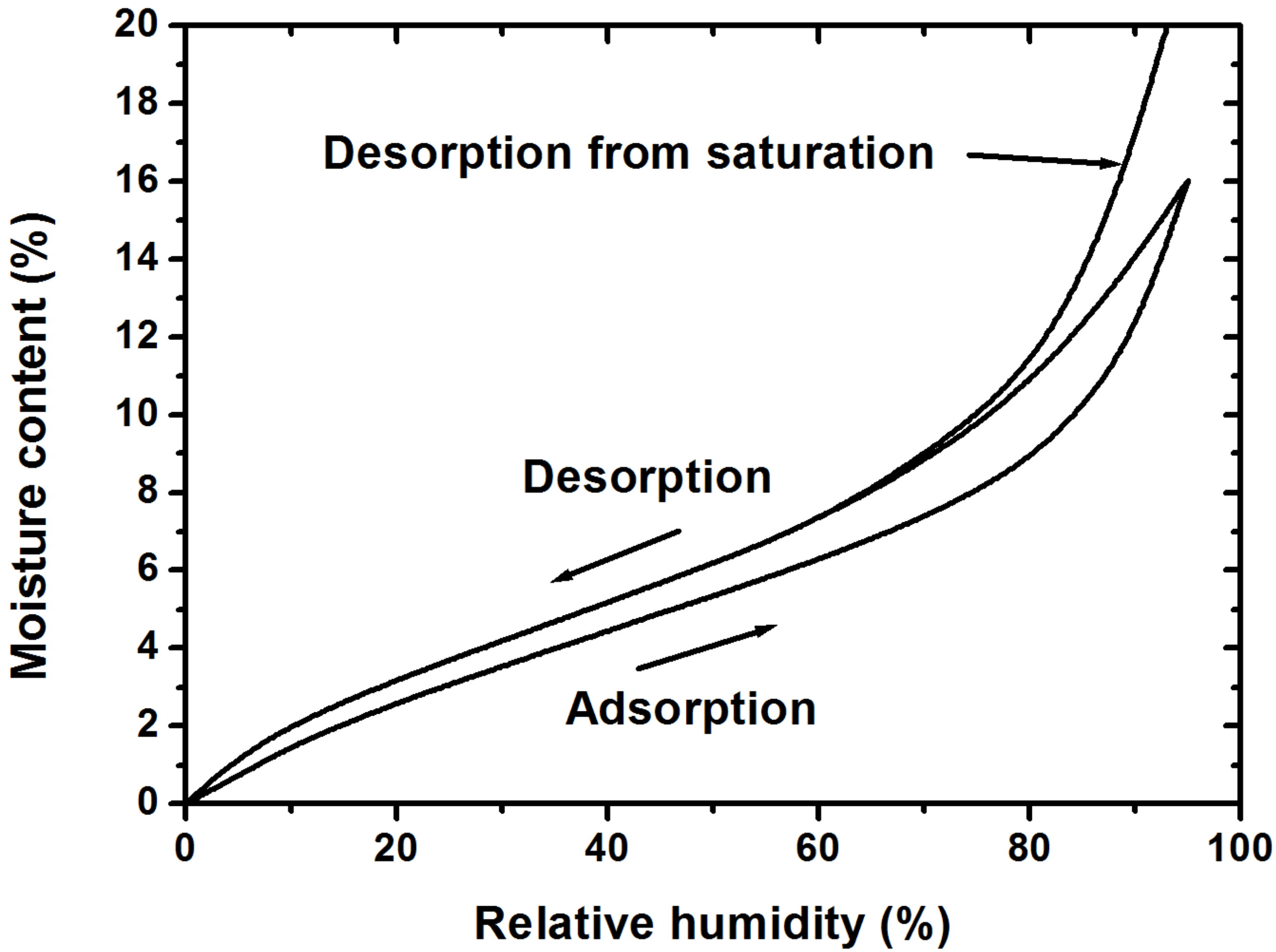
STRAMIT INTERNATIONAL

UNIVERSITY OF BATH

UNIVERSITÉ DE RENNES 1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°636835.

HYSTERESIS



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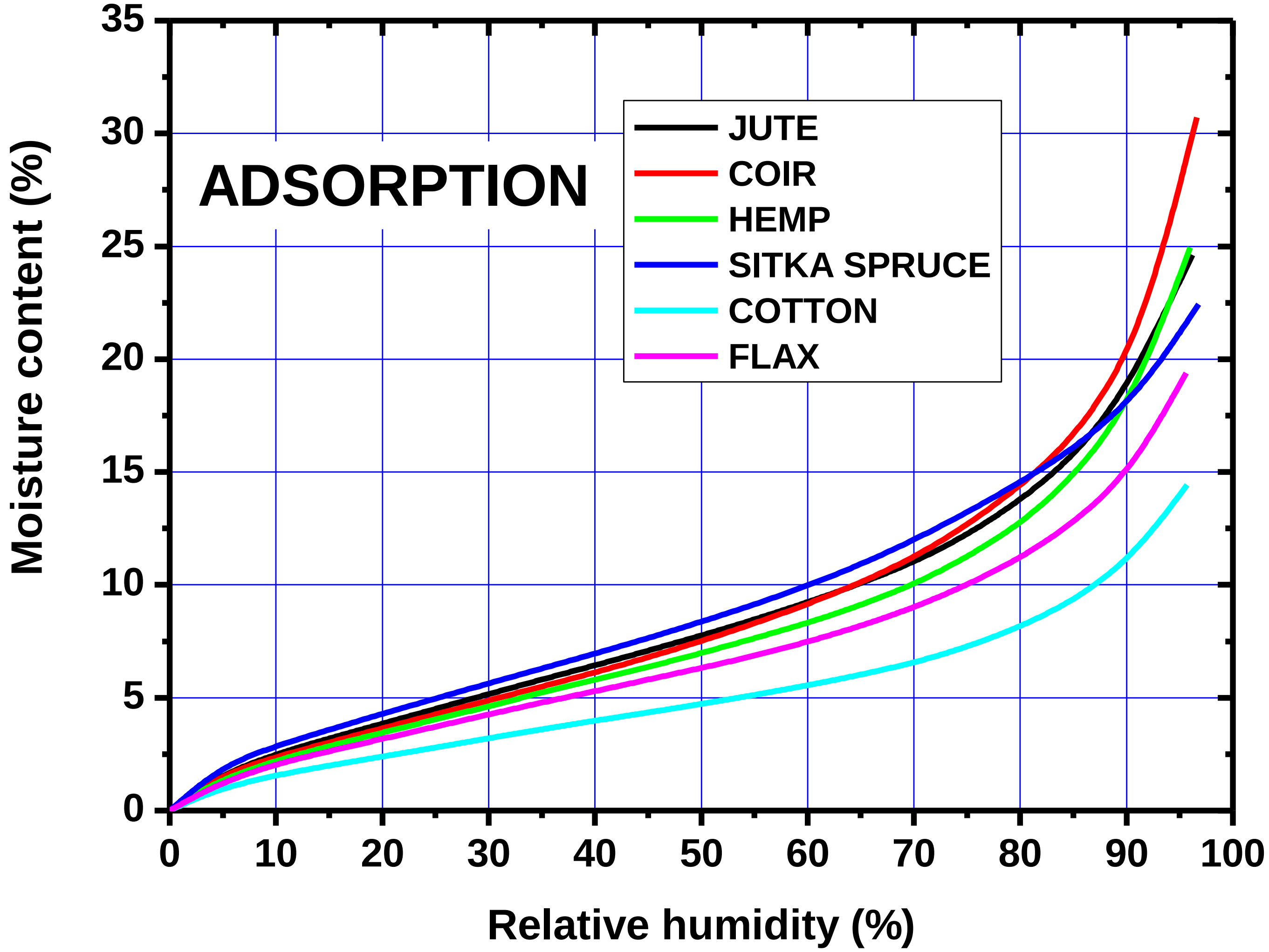
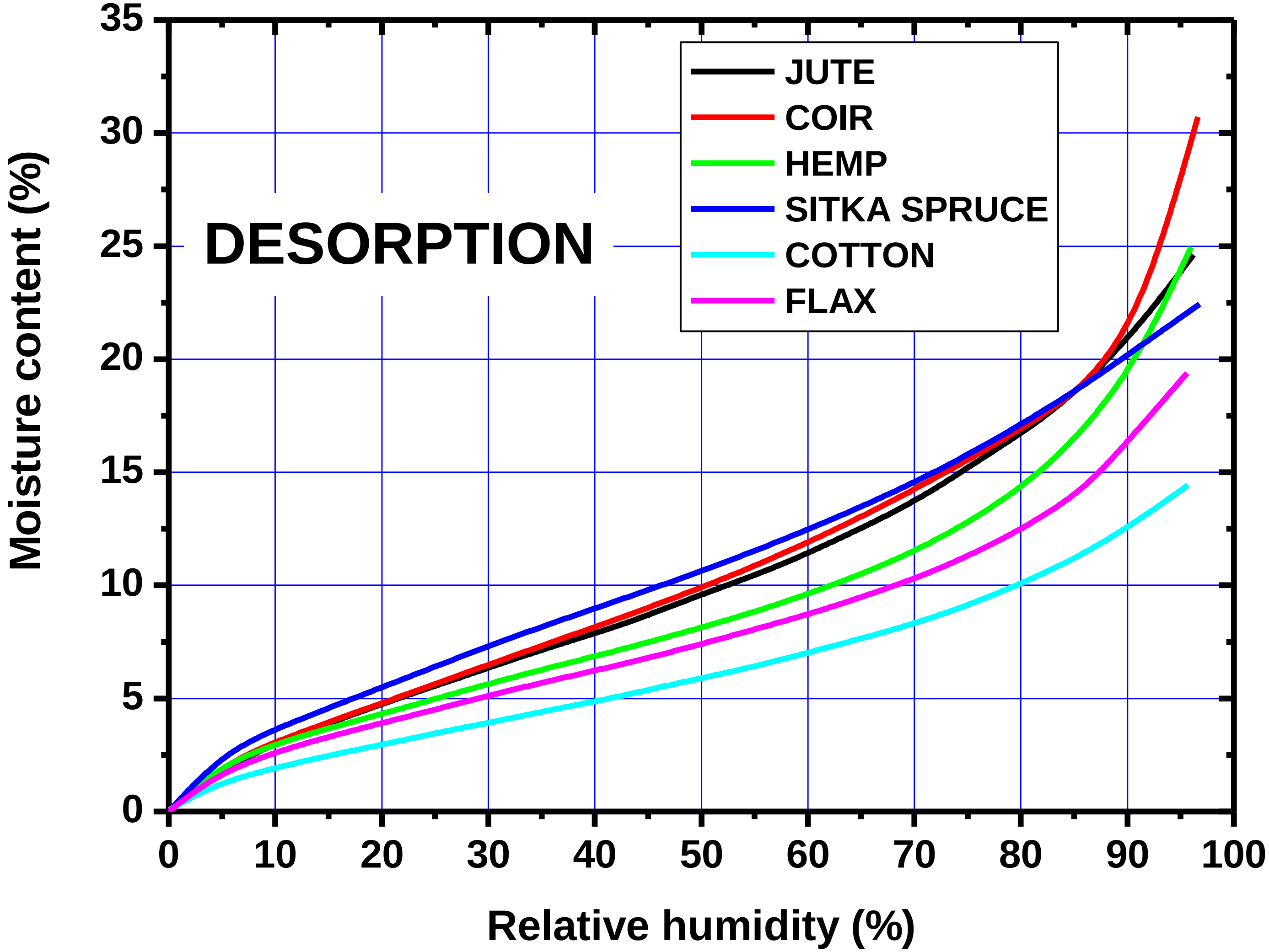
WHY DO WE GET HYSTERESIS?

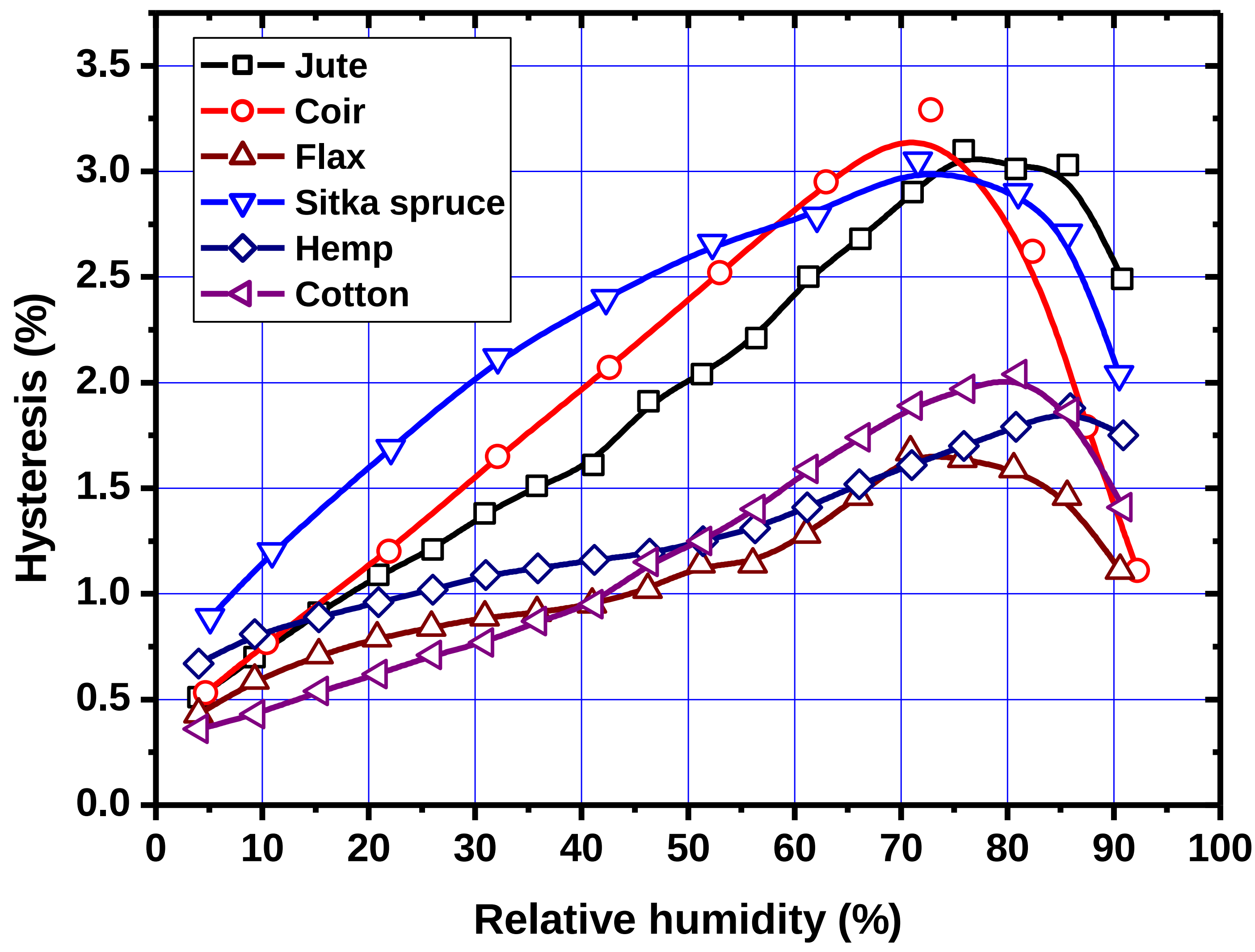
- Questions:

- What is the origin of sorption hysteresis?
- Can the mechanism for hysteresis be linked to the sorption kinetic behaviour?

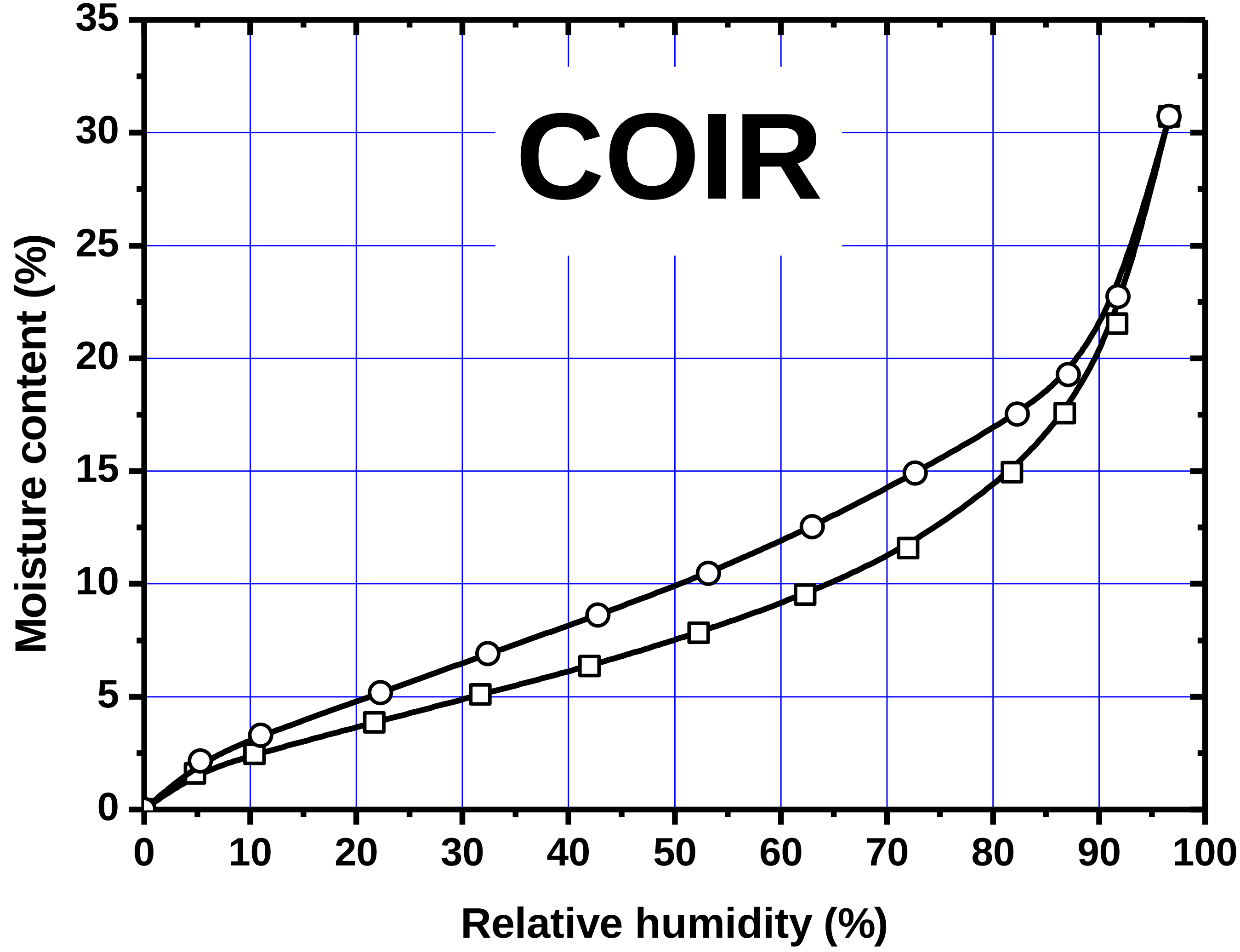


ADSORPTION
JUTE
COIR
HEMP
SITKA SPRUCE
COTTON
FLAX
Moisture content (%)
Relative humidity (%)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90
100


DESORPTION
JUTE
COIR
HEMP
SITKA SPRUCE
COTTON
FLAX
Moisture content (%)
Relative humidity (%)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90
100
JCH


Jute
Coir
Flax
Sitka spruce
Hemp
Cotton
Hysteresis (%)
Relative humidity (%)
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

JCH


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

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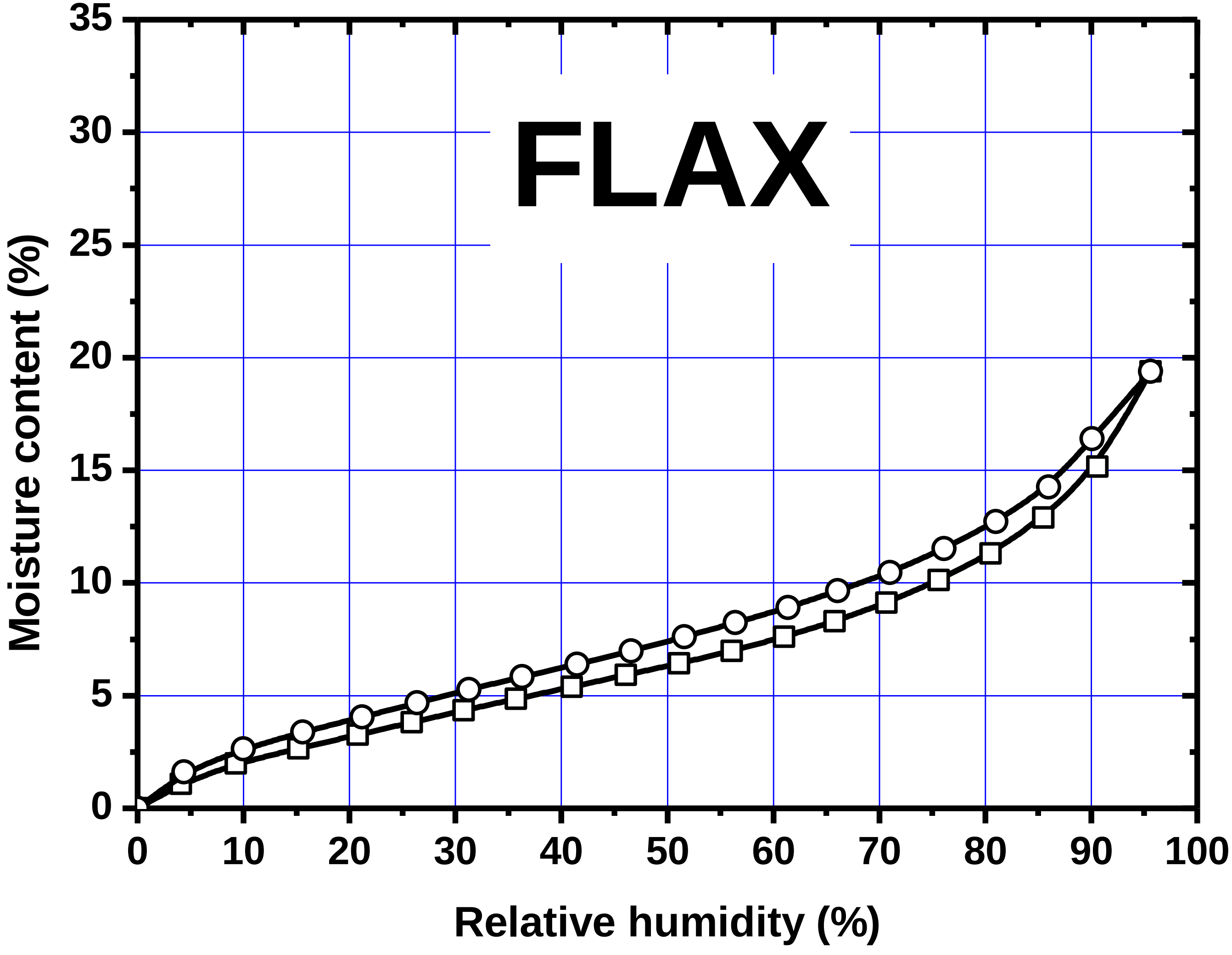
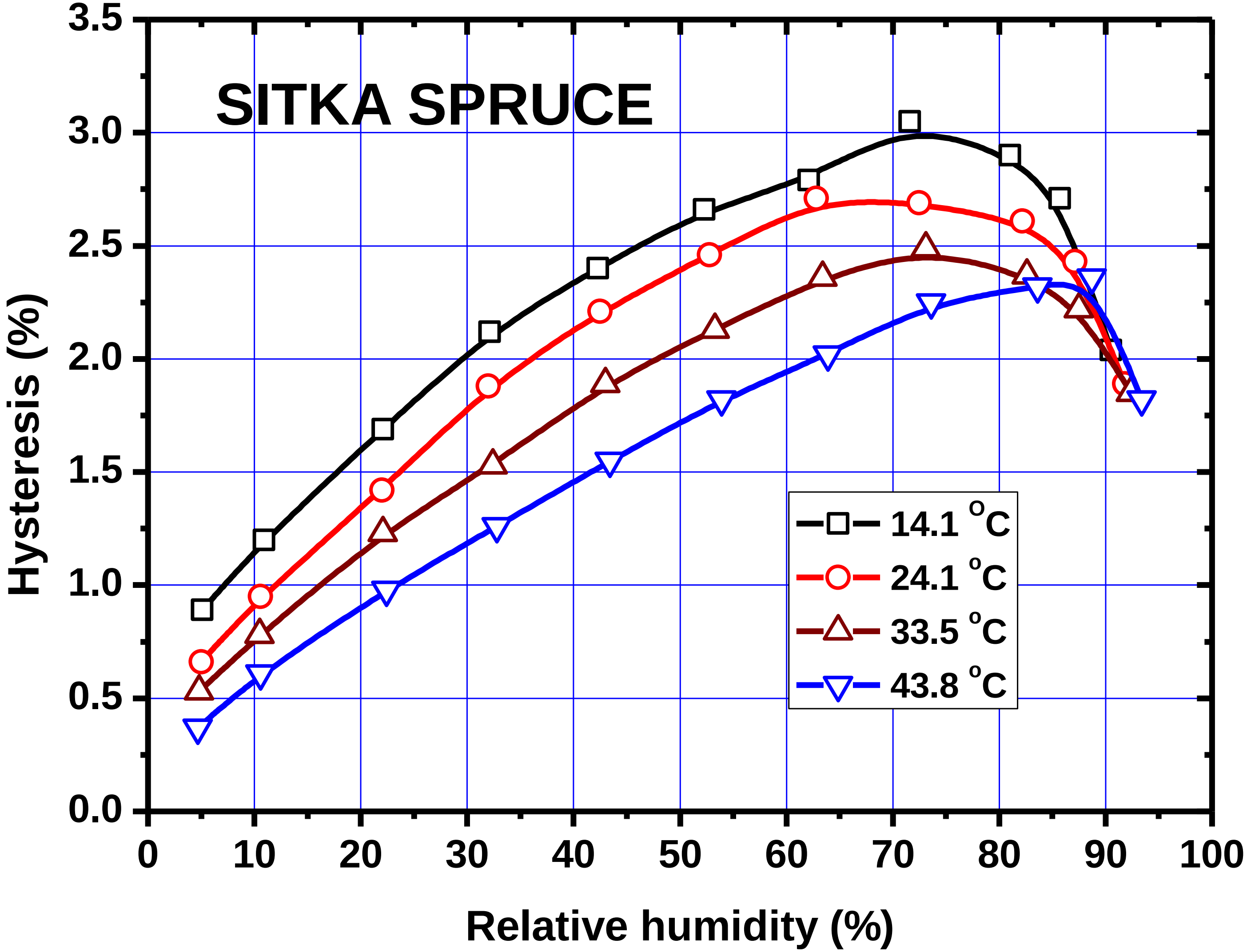

FLAX
Moisture content (%)
Relative humidity (%)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90
100

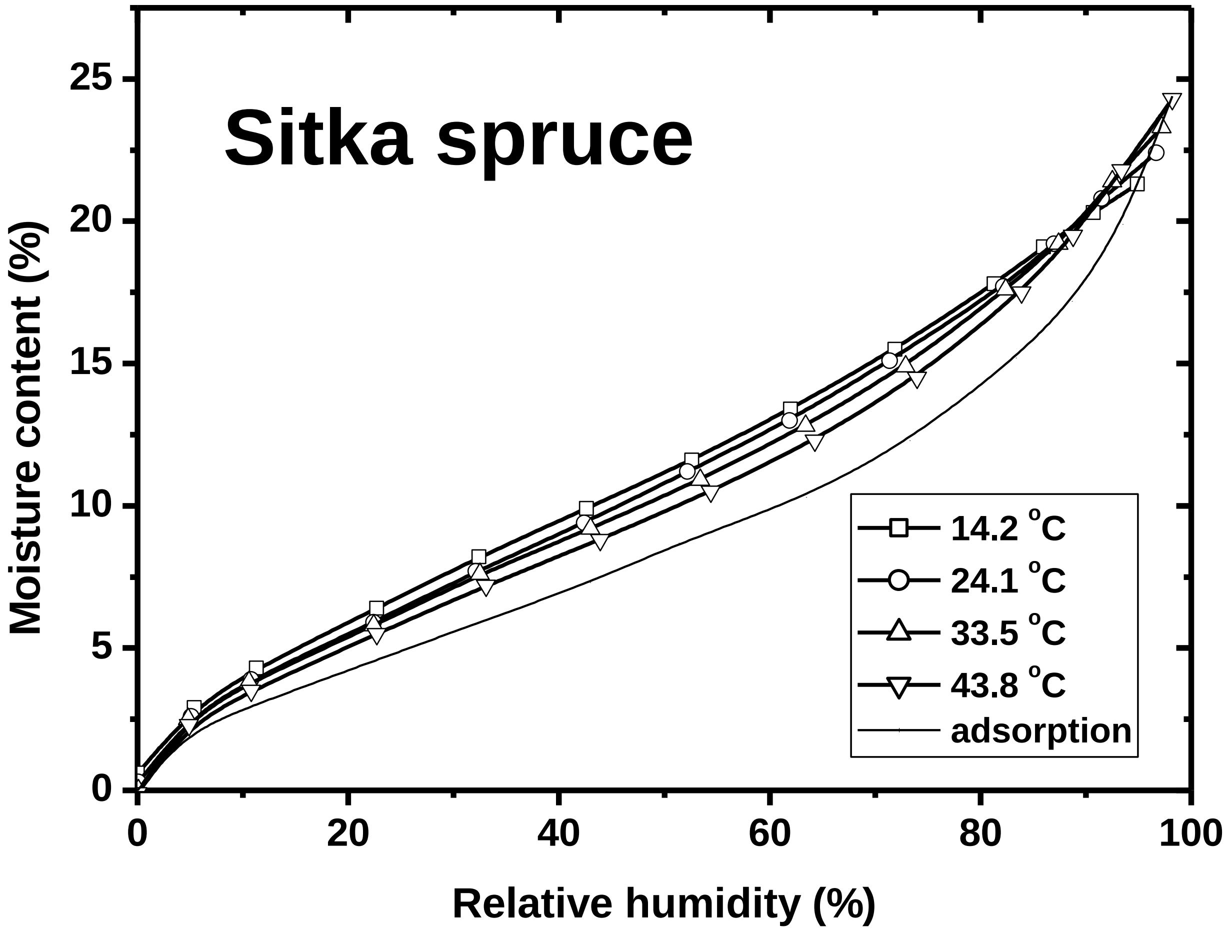
HYSTERESIS

- Model by Vrentas and Vrentas
- Sorption onto a glassy solid below the glass transition temperature
- Hysteresis arises due to adsorption and desorption into/out of a material in different states

Hyesteresis



HYSTERESIS

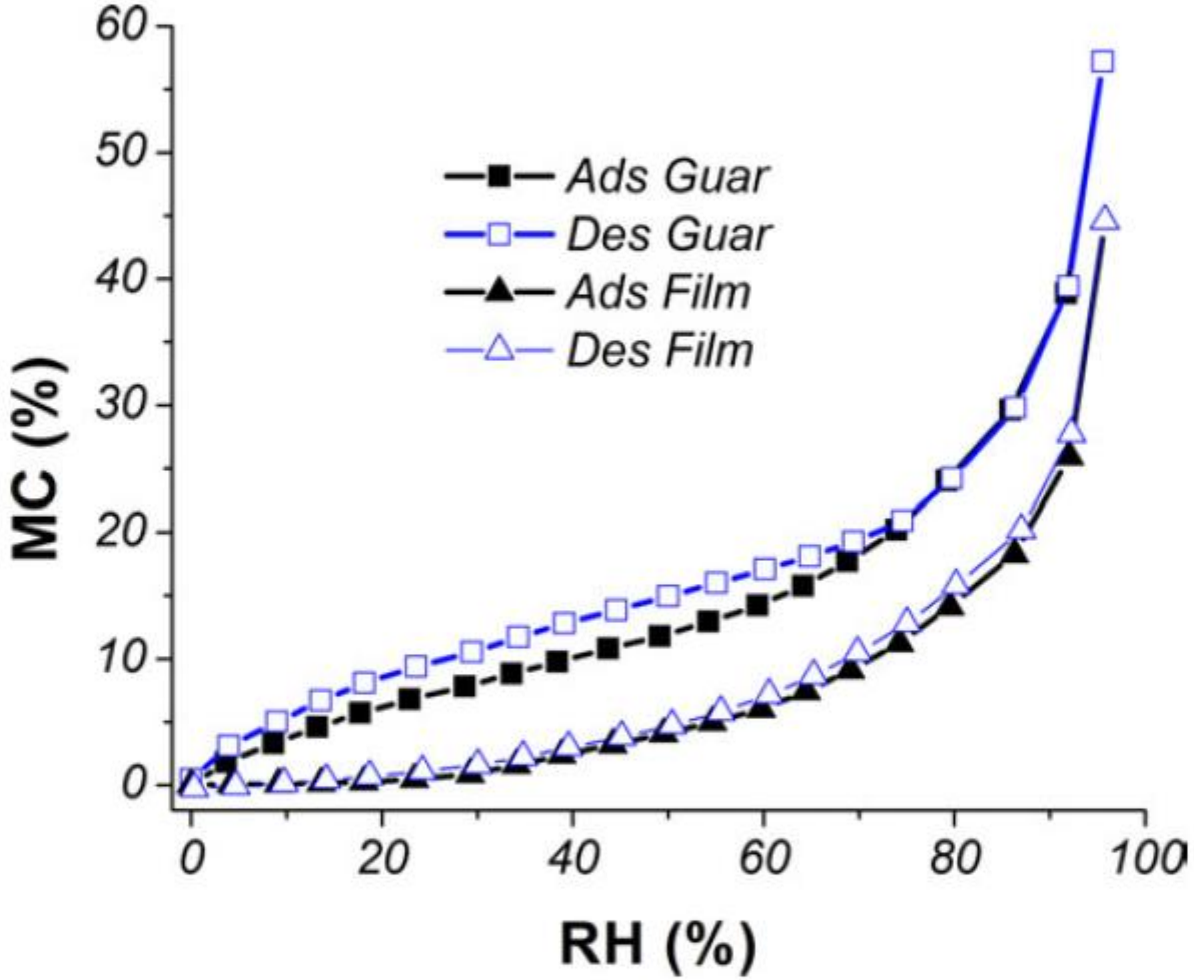


Sitka spruce
Moisture content (%)
Relative humidity (%)
0
5
10
15
20
25
0
20
40
60
80
100
14.2 °C
24.1 °C
33.5 °C
43.8 °C
adsorption

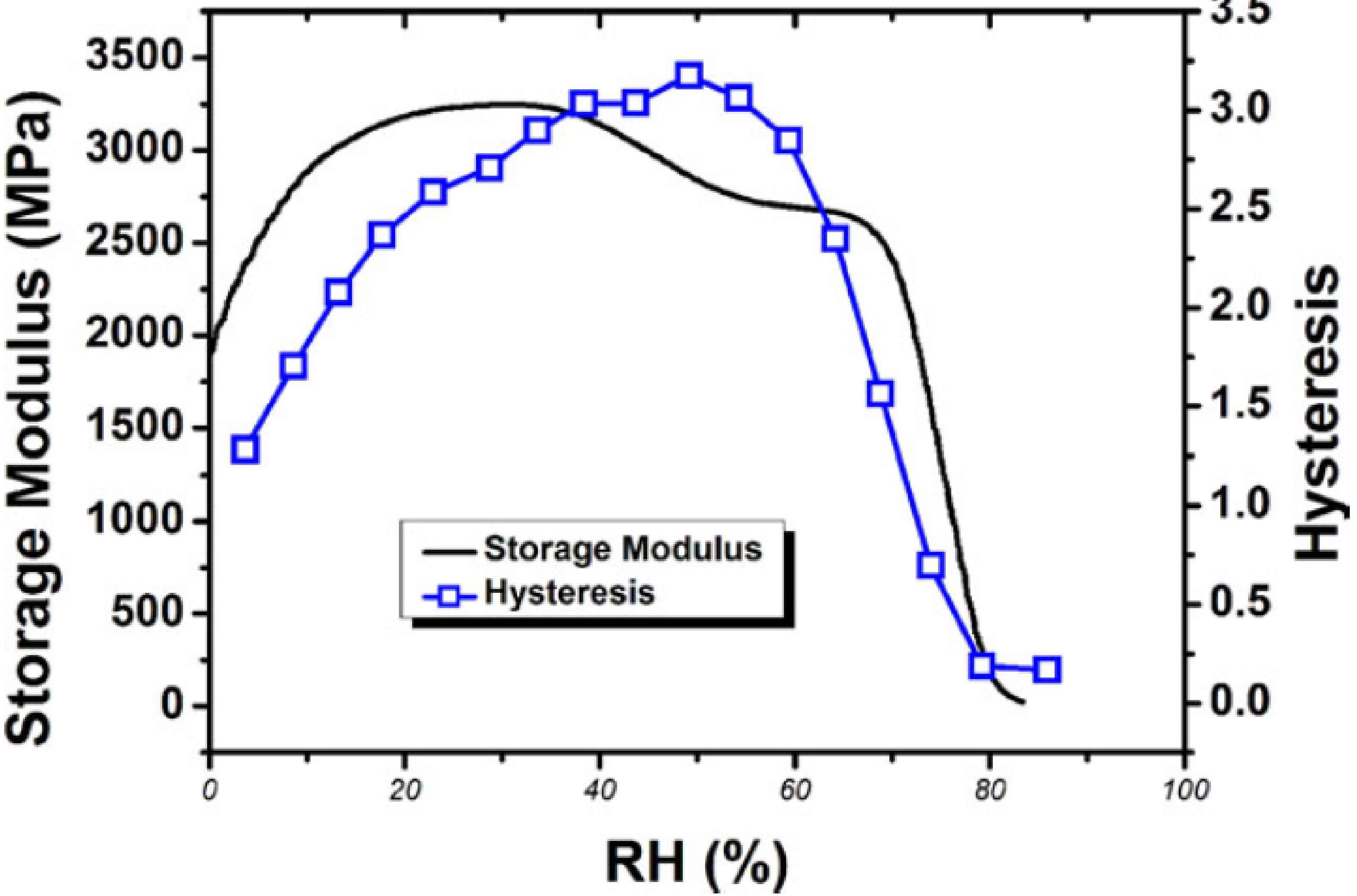
HYSTERESIS

The Water Vapor Sorption Behavior of a Galactomannan Cellulose Nanocomposite Film Analyzed Using Parallel Exponential Kinetics and the Kelvin-Voigt Viscoelastic Model

Barbara A. Keating,[1] Callum A. S. Hill,[2] Dongyang Sun,[2] Rob English,[2] Phil Davies,[3] Charles McCue[3]
[1]Department of Mechanical and Aerospace Engineering, The University of Strathclyde, Glasgow G1 1XJ, United Kingdom
[2]Forest Products Research Institute, Joint Research Institute for Civil and Environmental Engineering, Edinburgh Napier University, Edinburgh EH10 5DT, United Kingdom
[3]Waters, Atlas Park, Simonsway, Manchester M22 5PP, United Kingdom
Correspondence to: B. Keating (E-mail: barbara.keating@strath.ac.uk)

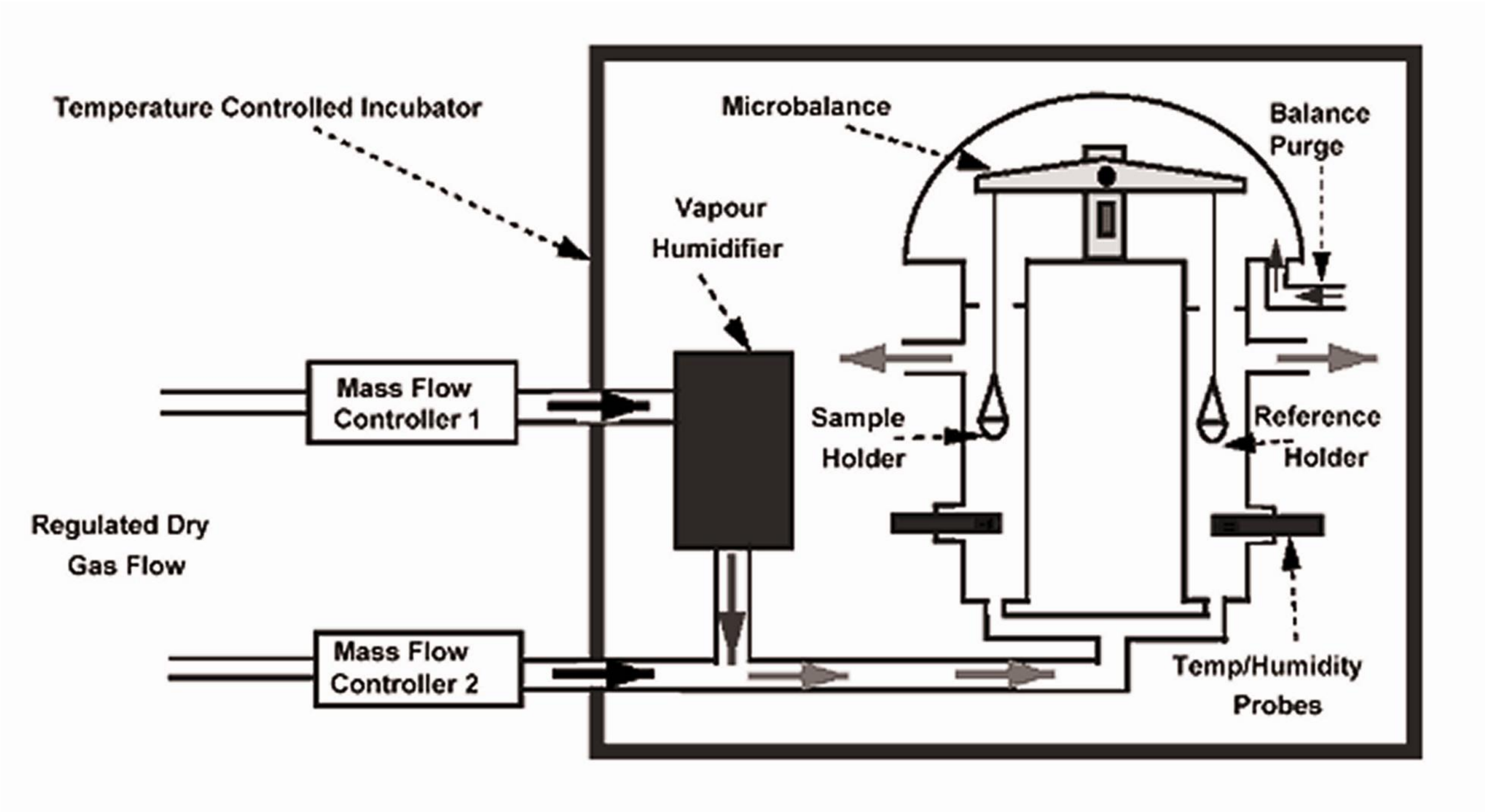


Ads Guar
Des Guar
Ads Film
Des Film
MC (%)
RH (%)
0
10
20
30
40
50
60
0
20
40
60
80
100

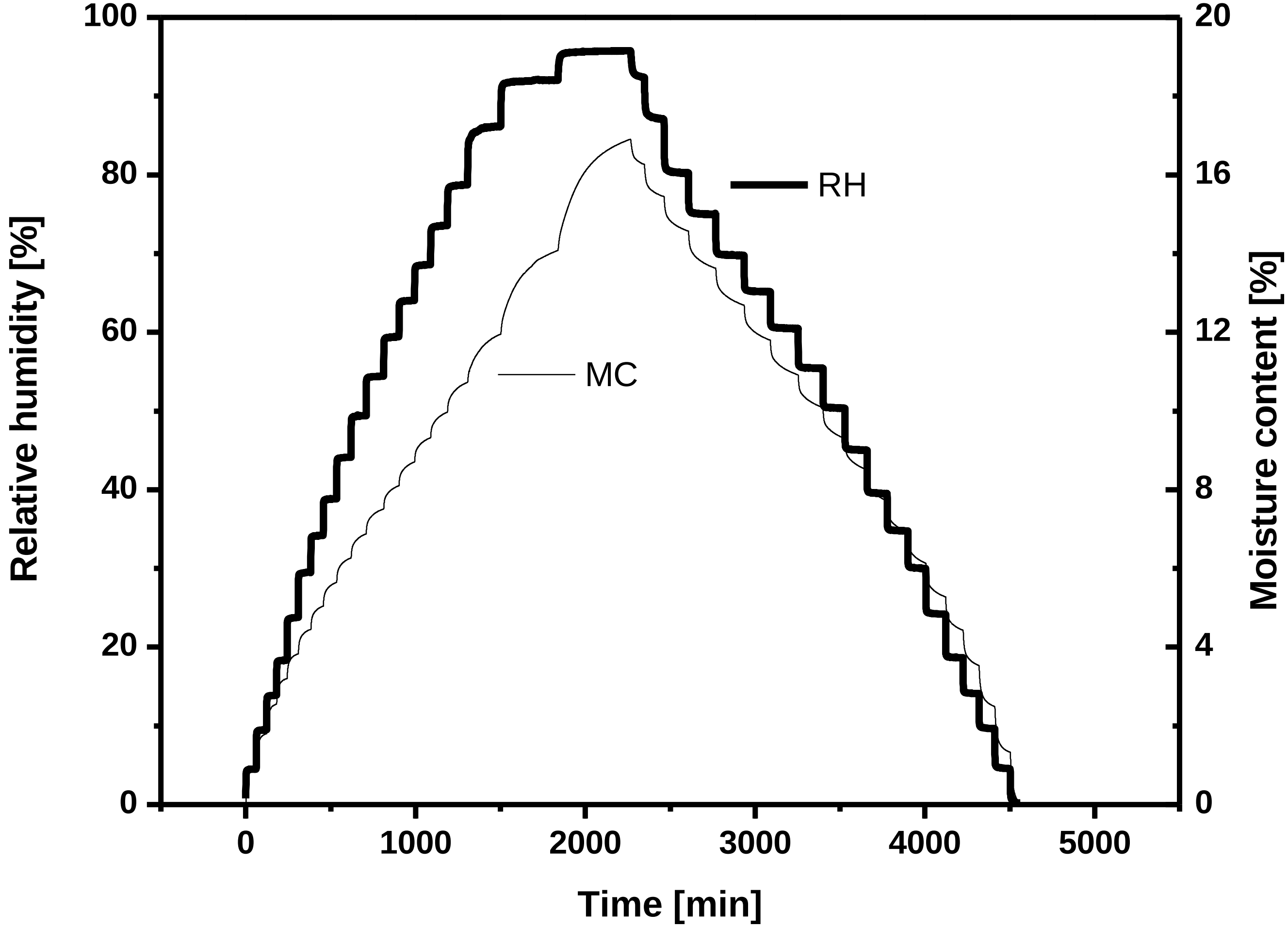


Storage Modulus (MPa)
3500
3000
2500
2000
1500
1000
500
0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Hysteresis
Storage Modulus
Hysteresis
0
20
40
60
80
100
RH (%)

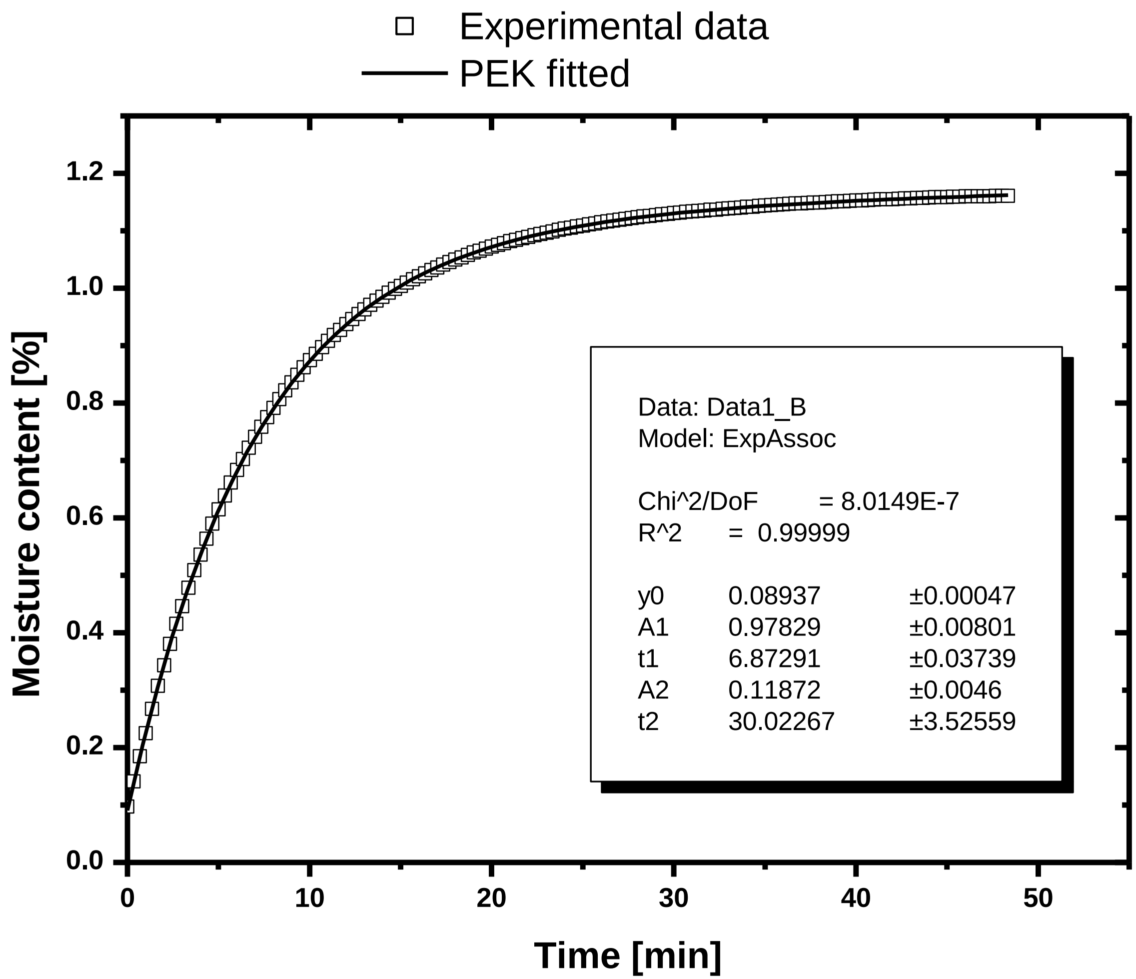
DVS APPARATUS



DVS RUN


100
80
60
40
20
0
Relative humidity [%]
20
16
12
8
4
0
Moisture content [%]
0
1000
2000
3000
4000
5000
Time [min]
RH
MC

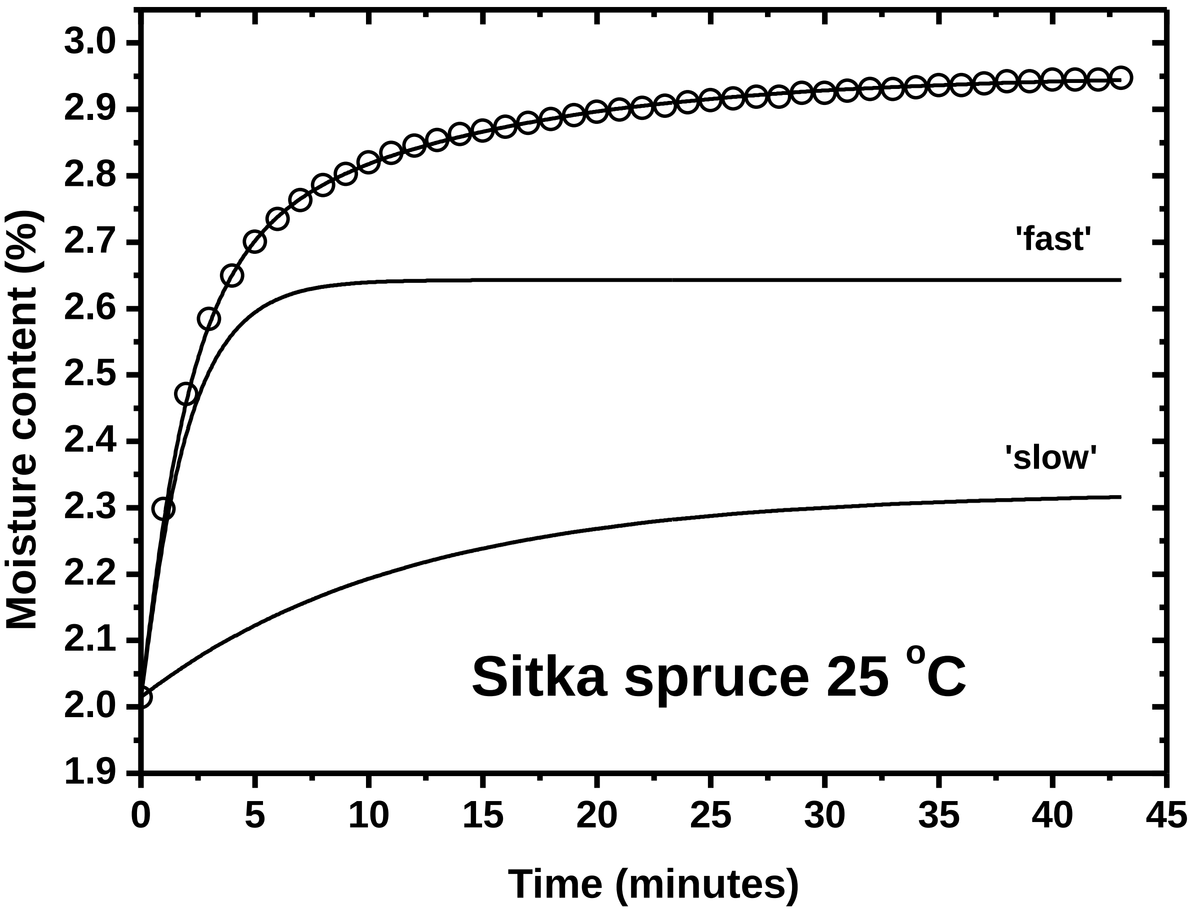
SORPTION KINETICS



SORPTION KINETICS - PEK MODEL

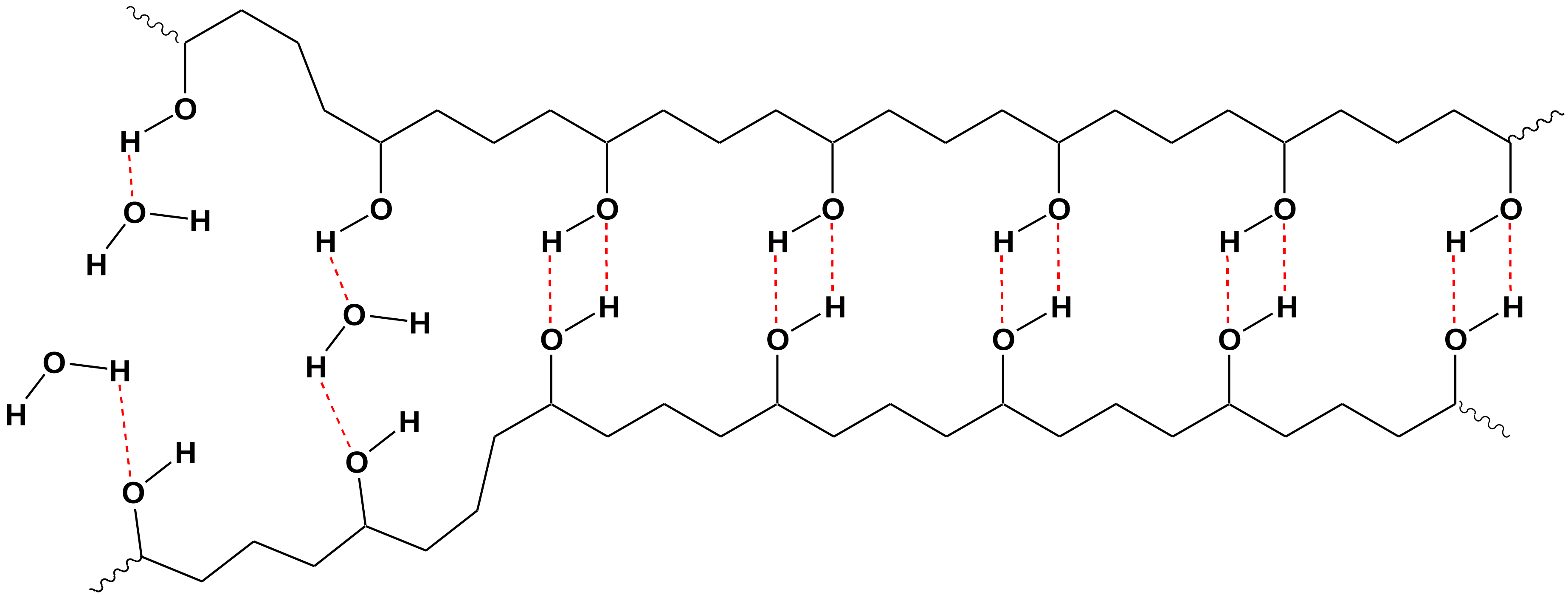
- $MC = MC_0 + MC_1(1 - e^{-t/t_1}) + MC_2(1 - e^{-t/t_2}$

PEK MODEL



Moisture content (%)
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
0
5
10
15
20
25
30
35
40
45
Time (minutes)
'fast'
'slow'
Sitka spruce 25 °C

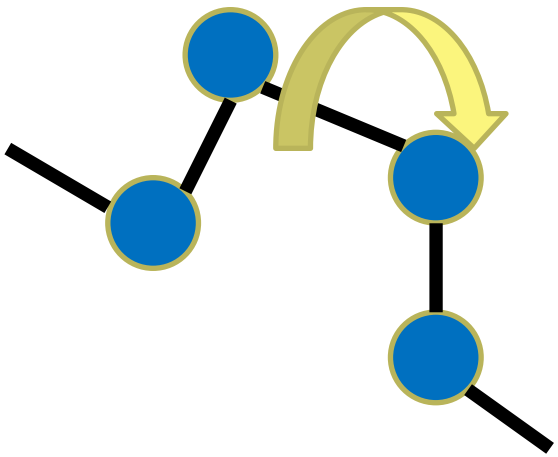
KINETICS

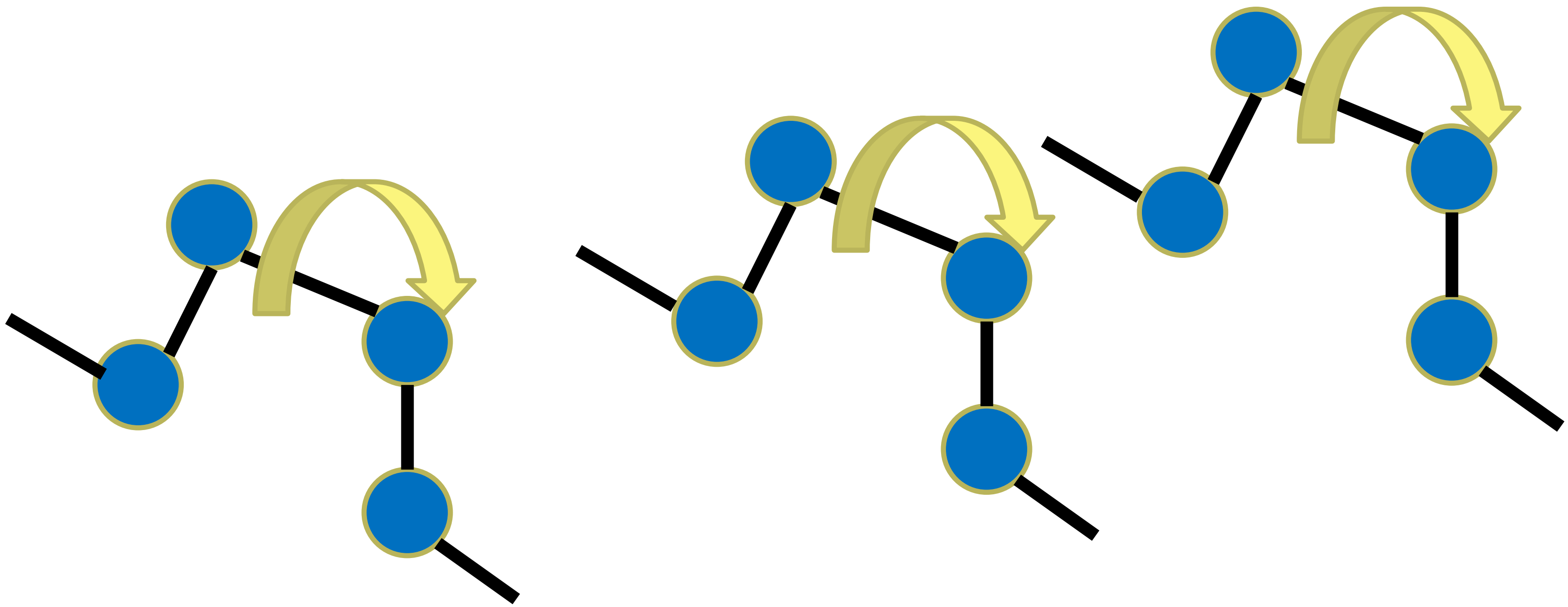


Cooperative Relaxation Processes in Polymers

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

SHIRO MATSUOKA,[1] ARTURO HALE[2]

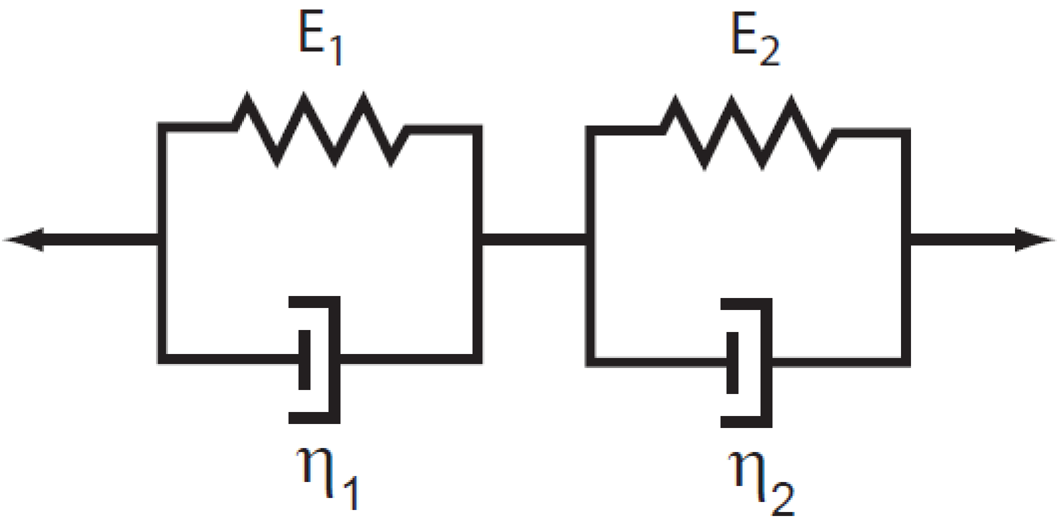




KELVIN-VOIGT

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

KELVIN-VOIGT MODEL



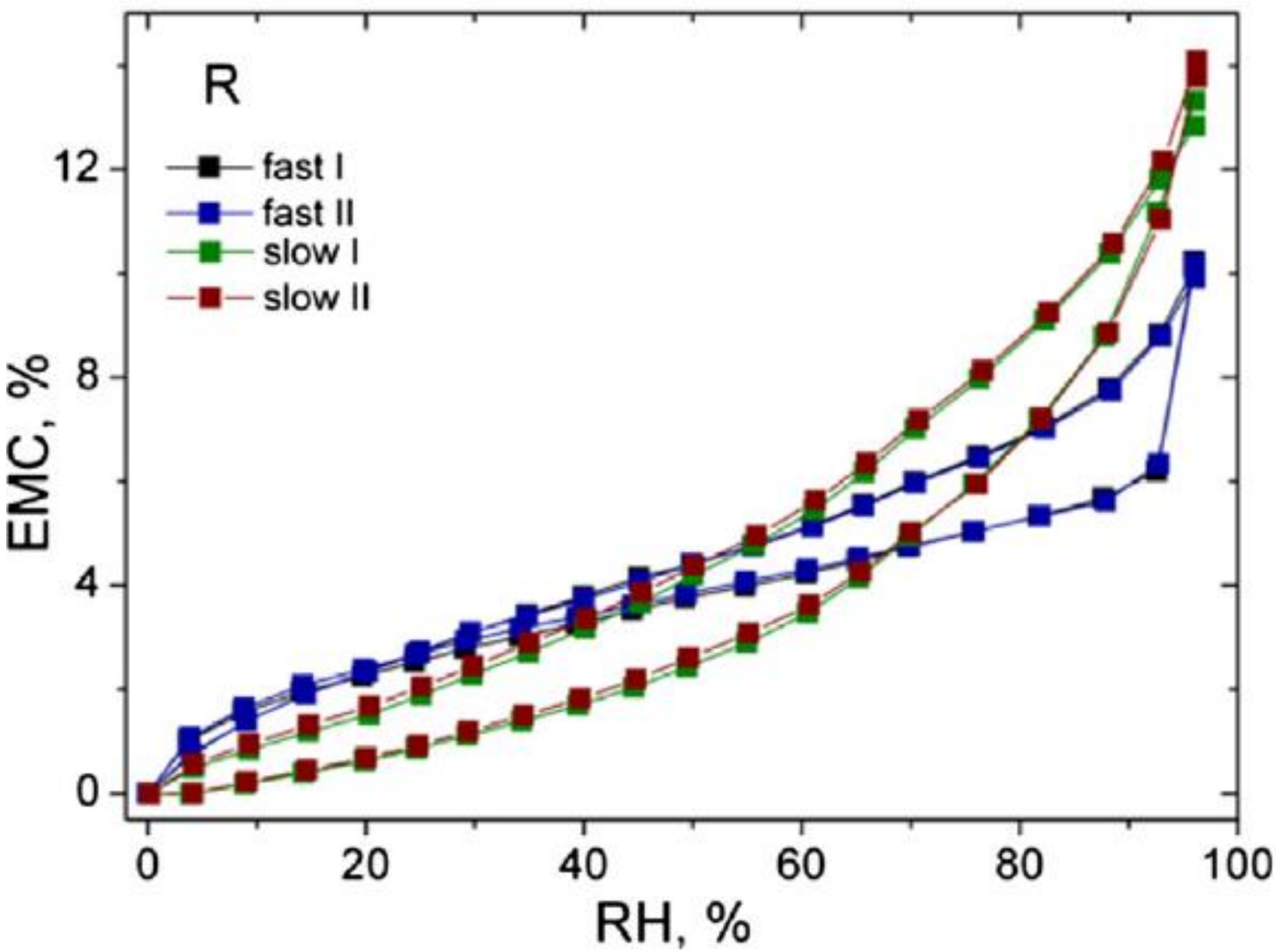
$$\varepsilon = (\sigma_0 / E)[1 - \exp(-t/\varphi)]$$

The water vapour adsorption–desorption behaviour of naturally aged *Tilia cordata* Mill. wood

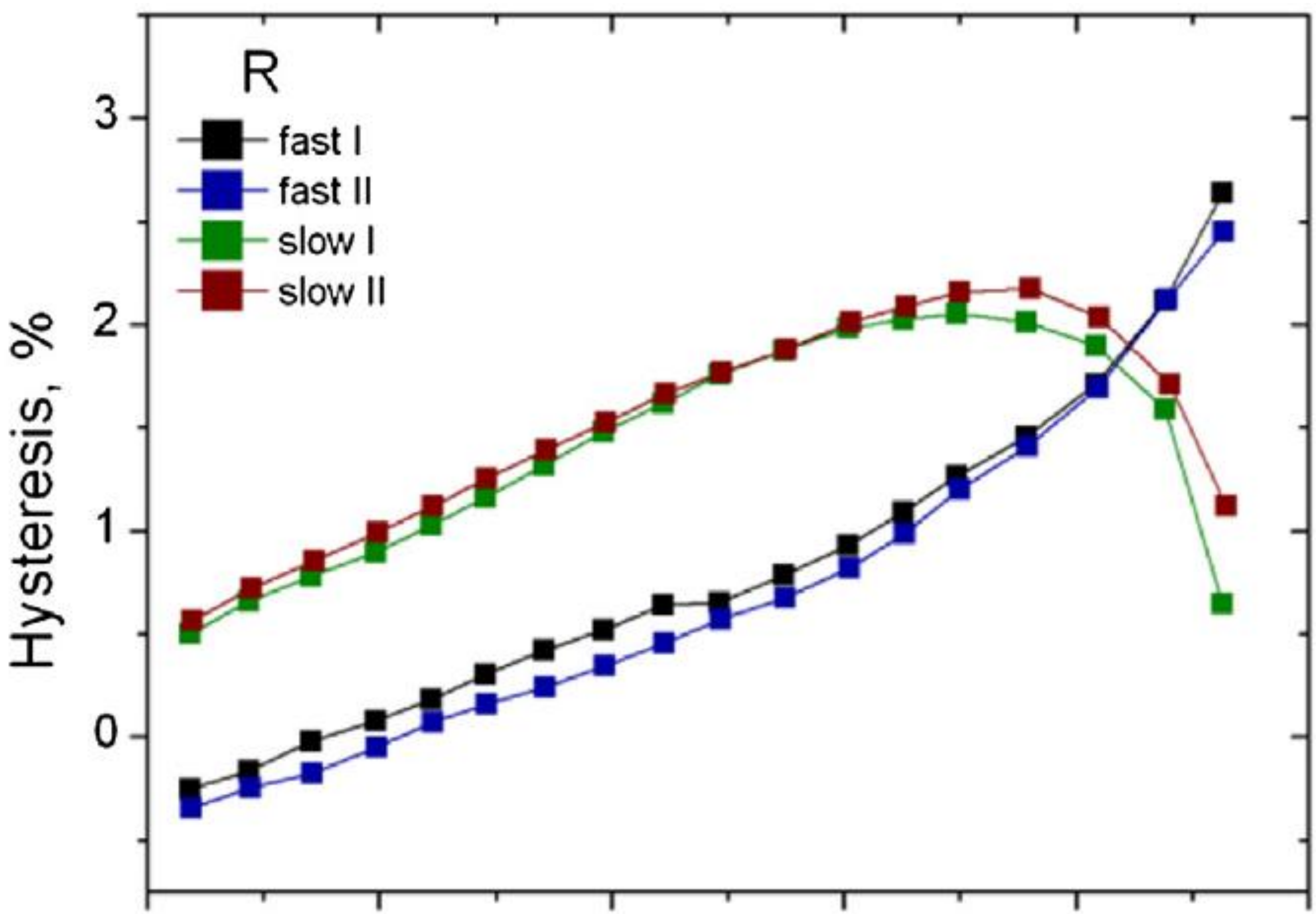
Carmen-Mihaela Popescu [a,*], Callum A.S. Hill [b]

[a] "Petru Poni" Institute of Macromolecular Chemistry of Romanian Academy, 700487 Iasi, Romania
[b] Forest Products Research Institute, Edinburgh Research Partnership Joint Research Institute in Civil and Environmental Engineering, Edinburgh Napier University, Edinburgh EH10 5DT, UK

Polymer Degradation and Stability 98 (2013) 1804–1813



R
fast I
fast II
slow I
slow II
EMC, %
RH, %
0
4
8
12
0
20
40
60
80
100

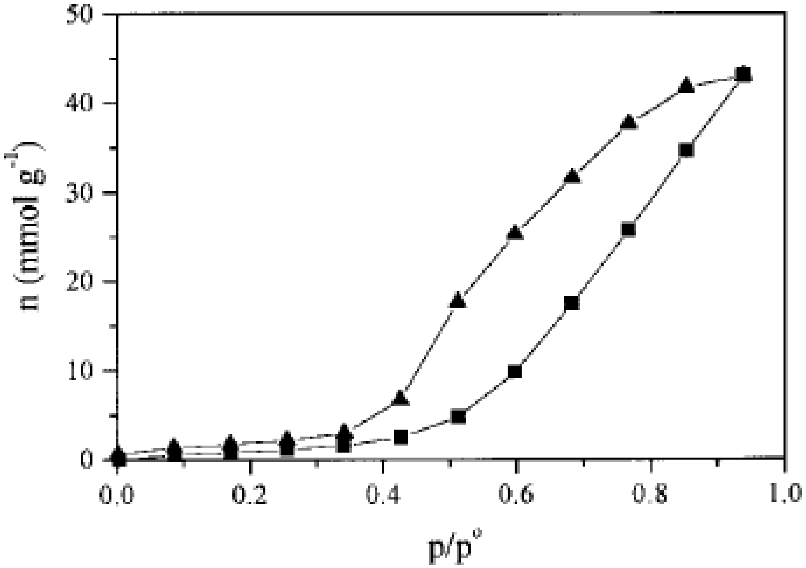

R
fast I
fast II
slow I
slow II
Hysteresis, %
3
2
1
0

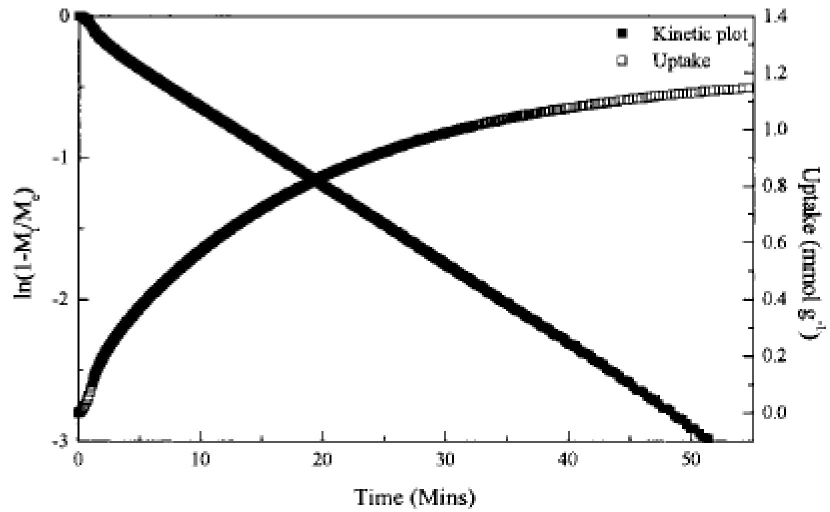
CHARCOAL

Langmuir **1998**, *14*, 3858–3864

Diffusion Barriers in the Kinetics of Water Vapor Adsorption/Desorption on Activated Carbons

A. W. Harding, N. J. Foley, P. R. Norman,† D. C. Francis,† and K. M. Thomas*





3.2. Adsorption Kinetics. The kinetics of water vapor adsorption on carbon C1 have been shown to follow a linear driving force mass transfer (LDF) model.[9]

$$M_t/M_e = 1 - e^{-kt}$$

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CONCLUSIONS

- A 'mechanical' interpretation gives results that are reasonable
- Fast process is probably diffusion-limited and slow process relaxation-limited
- Still to be investigated is the link between sorption hysteresis and kinetics
- Sorption is controlled by energy criteria
- So what is the role of OH groups?

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