

Warsaw  
19-20 Oct, 2006

# Transverse shrinkage of poplar tension wood at cell wall level

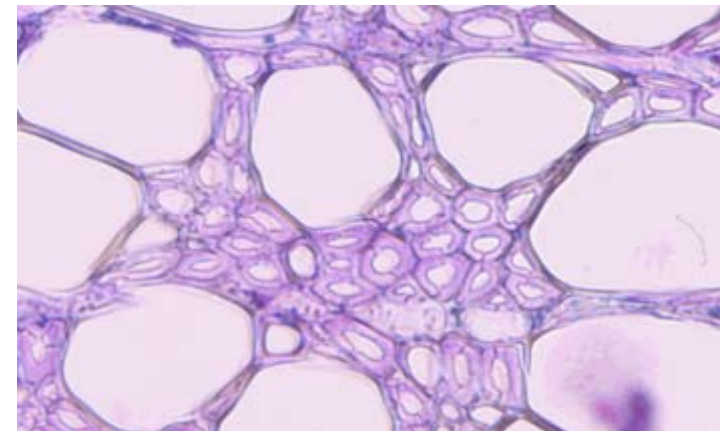
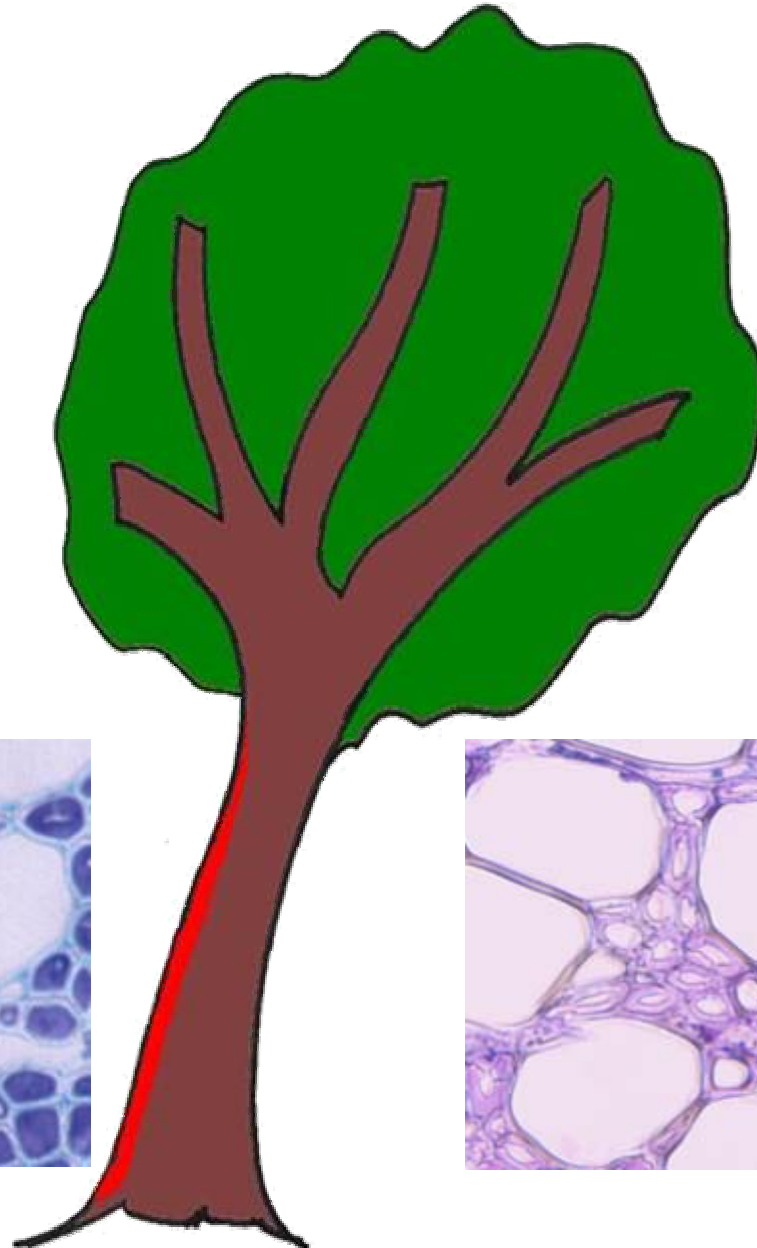
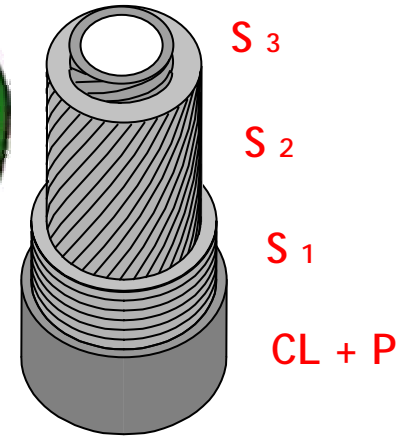
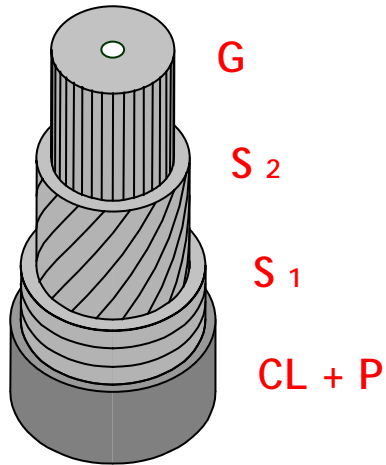
*Changhua FANG<sup>1,2</sup>, Bruno CLAIR<sup>1</sup>,  
Joseph GRIL<sup>1</sup>, Shengquan LIU<sup>2</sup>*

- 1) *Laboratoire de Mécanique et Génie Civil, University Montpellier 2, France*  
2) *Forest Products Department, Anhui Agricultural University, Hefei, China*



- **INTRODUCTION**

# Tension wood and gelatinous layer

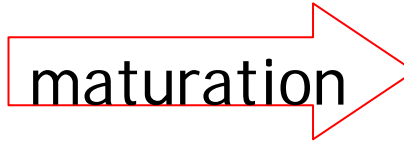


Tension wood

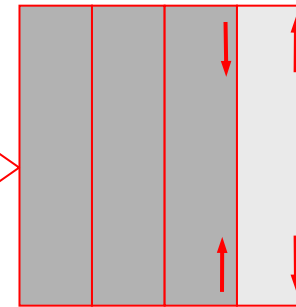
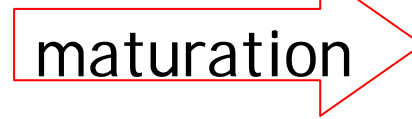
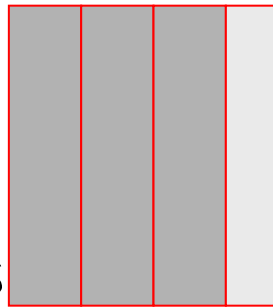
Normal wood

# Growth stresses

Single cell

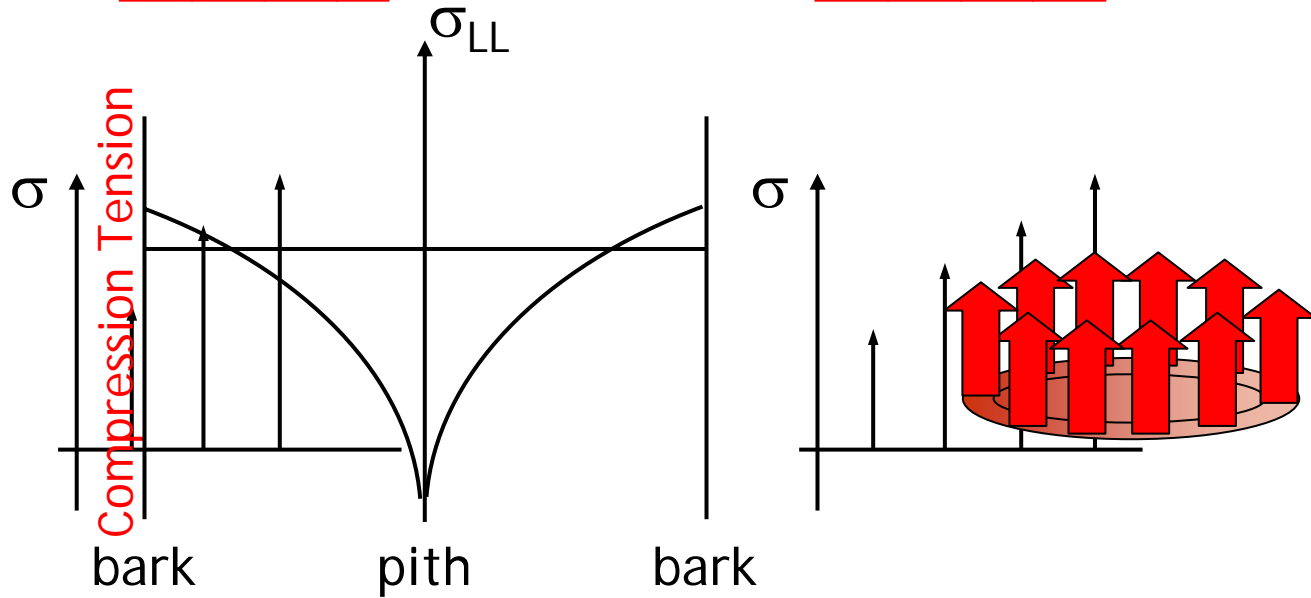


The same cell sticking to older cells



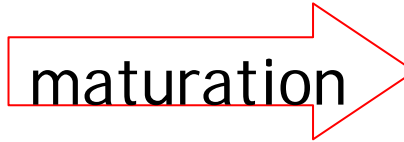
compression  
tension

Stress profiles

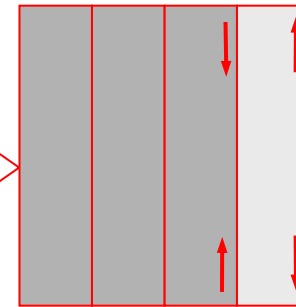
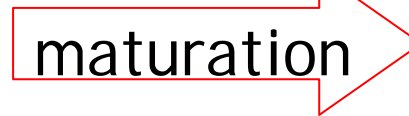
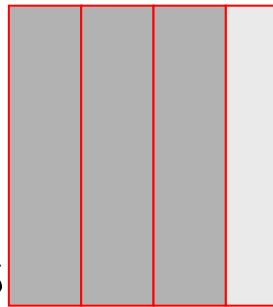


# Growth stresses

Single cell

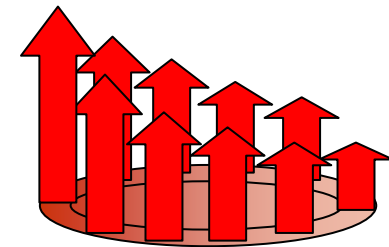
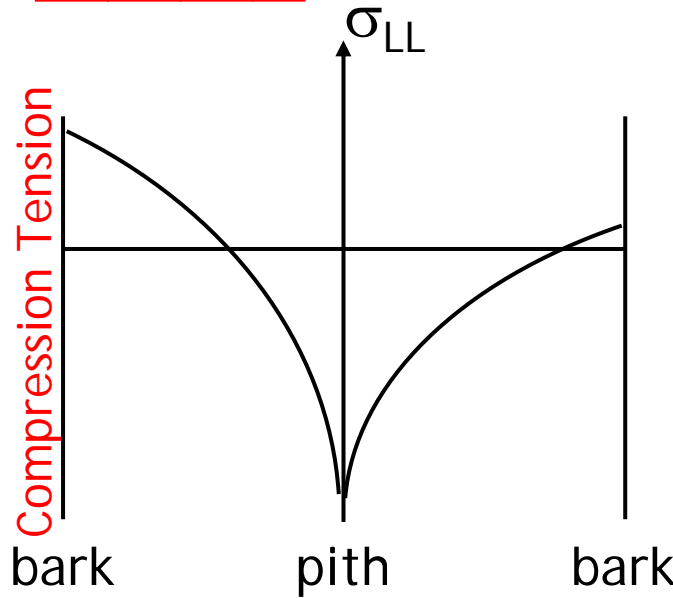


The same cell sticking to older cells



compression

tension

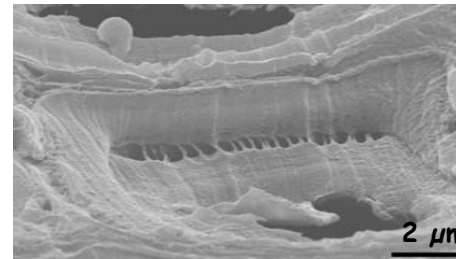
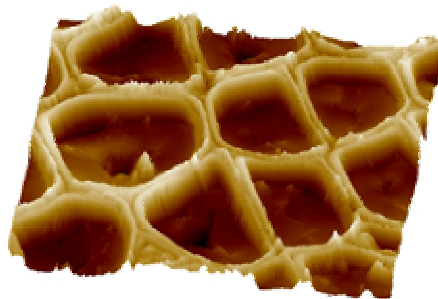


# Tension wood shrinkage

- Longitudinal shrinkage

Higher in tension wood than in normal wood

- 1) High longitudinal shrinkage is produced by S1 layer, G-layer being unable to prevent it.
- 2) Higher longitudinal shrinkage in G-layer than in other layers. (After B.Claire et al. 2001)



- Transverse shrinkage

Contradictory results were found by different researchers.

Washusen(2001) and Clair(2001):Higher in tension wood.

Arganbright(1970) and Barefoot(1963):Lower in tension wood.

# Objective

In this paper we concentrate on **transverse** shrinkage:

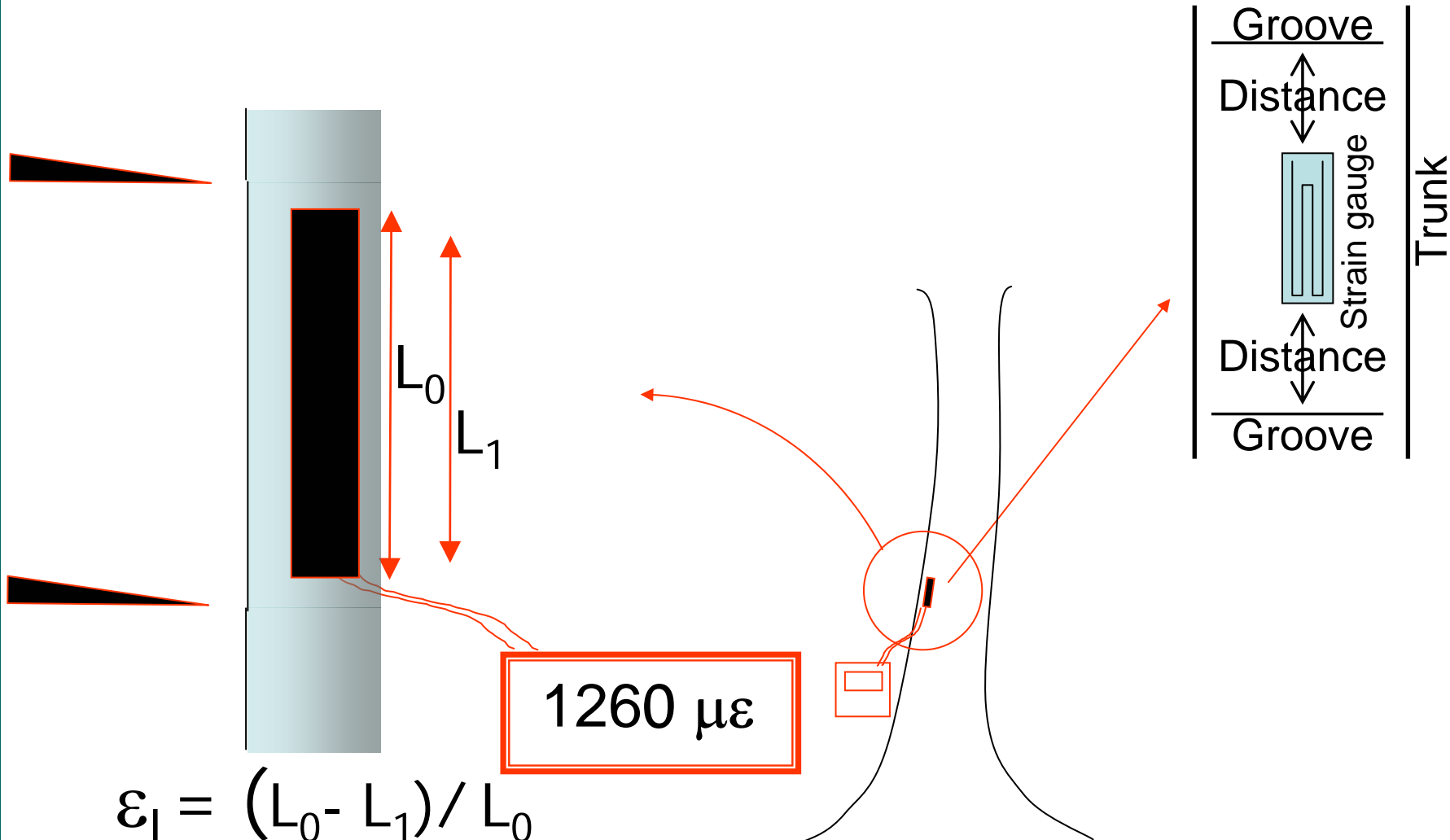
- At the microscopic level (0.5 - 10  $\mu\text{m}$ ):
  - Are there any shrinkage differences
    - between G-layer and the other layers?
    - among G-layers in different levels of tension wood?
- At the mesoscopic level (5 - 10 mm)
  - Are there any shrinkage differences
    - between normal wood and tension wood?
    - among different levels of tension wood?
- Contribution of G-layer and other layers to the mesoscopic shrinkage of tension wood.

- **Material and methods**

# Species

- Poplar tension wood (*Populus* I 45-51).
- Known to have a characteristic tension wood with G-fibres and to produce high longitudinal tensile stress.
- Tree was chosen according to its tilted shape.

# Growth Strain (GS)



1260  $\mu\epsilon$

$$\epsilon_L = (L_0 - L_1) / L_0$$

$$\mu\epsilon = \mu\text{m}/\text{m} = \epsilon \times 10^6$$

# Growth Strain (GS)

25 GS values from 100 to 2275 $\mu\epsilon$  were obtained.

None or very few G-fibre when  $GS \leq 610\mu\epsilon$

*Shrinkage measurement at the cell wall level:*

2275  $\mu\epsilon$ , 1935  $\mu\epsilon$ , 1450  $\mu\epsilon$ , 1158  $\mu\epsilon$ , 816  $\mu\epsilon$ , 610  $\mu\epsilon$

*Shrinkage measurement at the mesoscopic scale:*

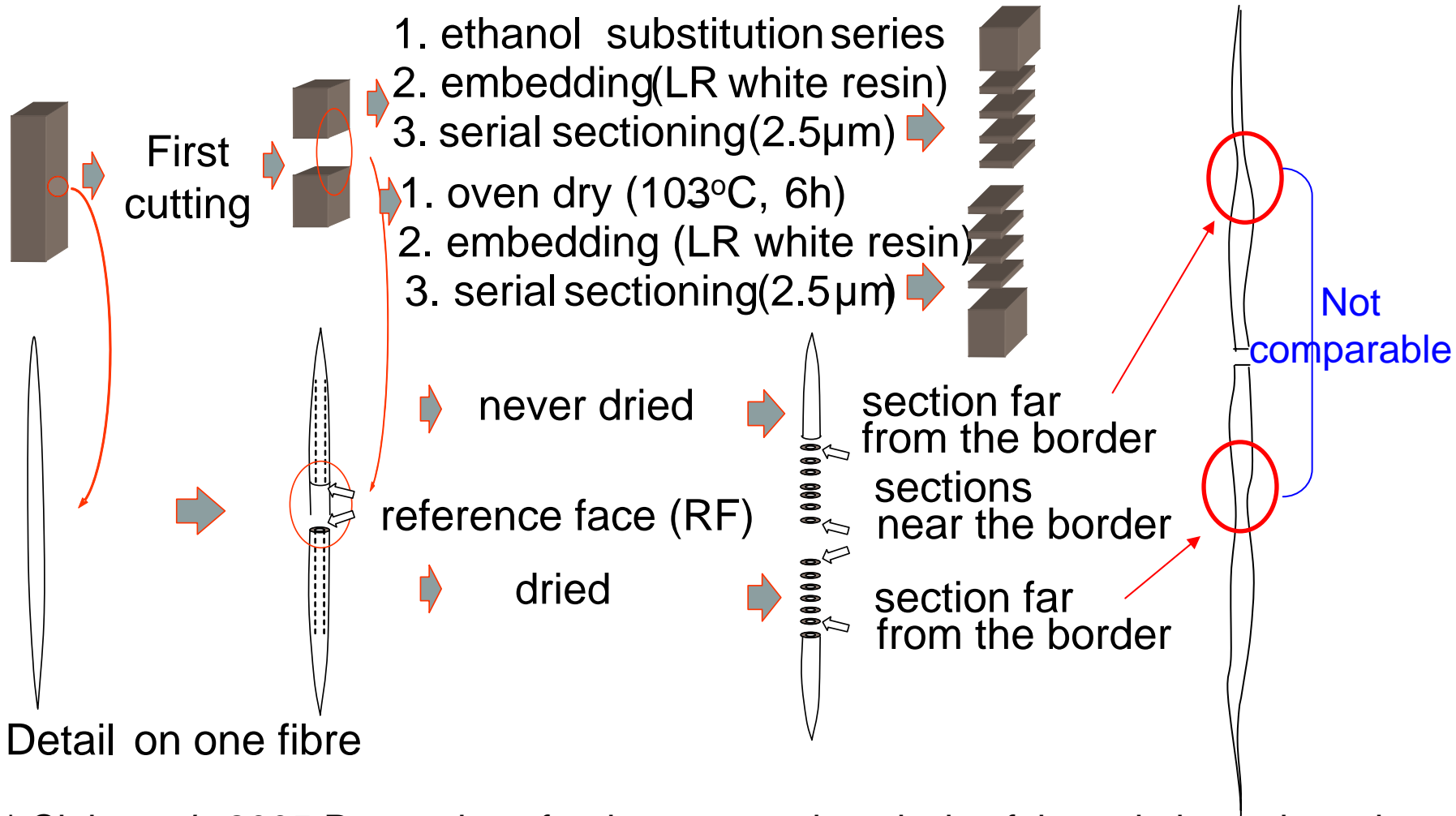
2275  $\mu\epsilon$ , 1935  $\mu\epsilon$ , 1450  $\mu\epsilon$ , 1158  $\mu\epsilon$ , 816  $\mu\epsilon$ , 610  $\mu\epsilon$ , 405  $\mu\epsilon$ , 168  $\mu\epsilon$

Tension Wood

Normal wood

# Shrinkage measurement at microscopic level

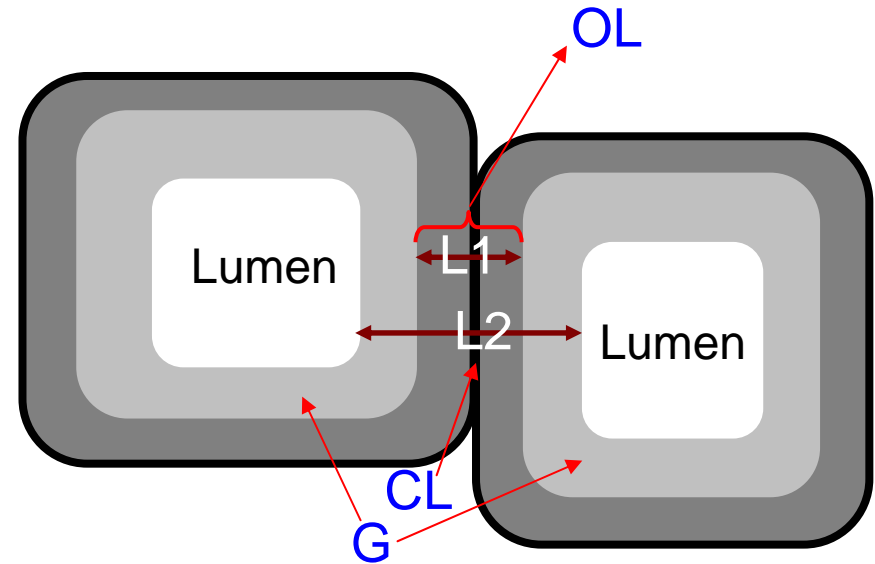
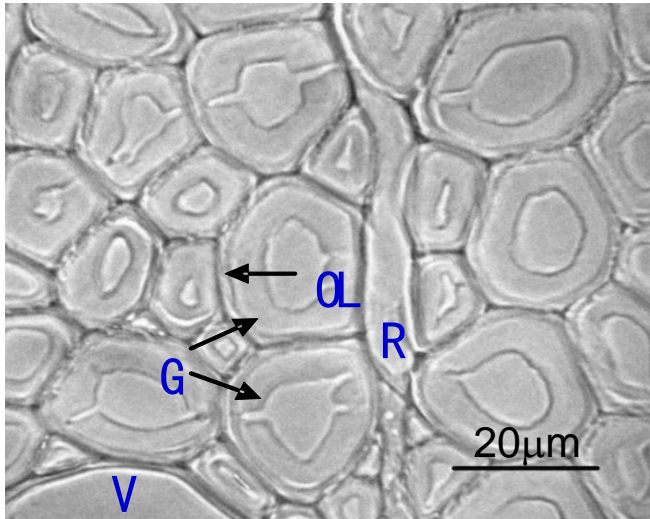
## → Samples preparation and Sectioning



\* Clair *et al.*, 2005 Precautions for the structural analysis of the gelatinous layer in tension wood. *IAWA Journal*, 26(2), 189-195.

# Shrinkage measurements at microscopic level

## → Measurements



G: G-layer; V: vessel; R: ray;

OL: Other layers including  $S_2(?)$ ,  $S_1$ , P, and compound lamella (CL).

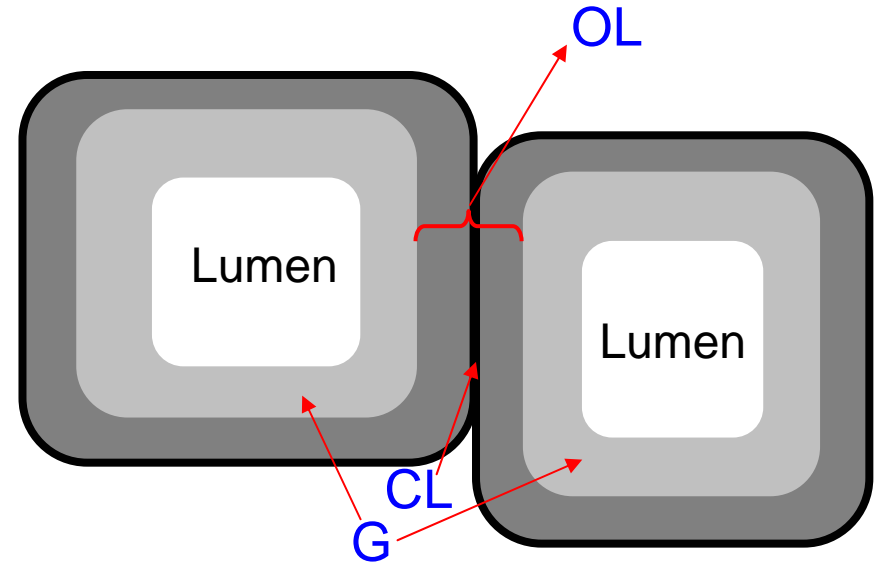
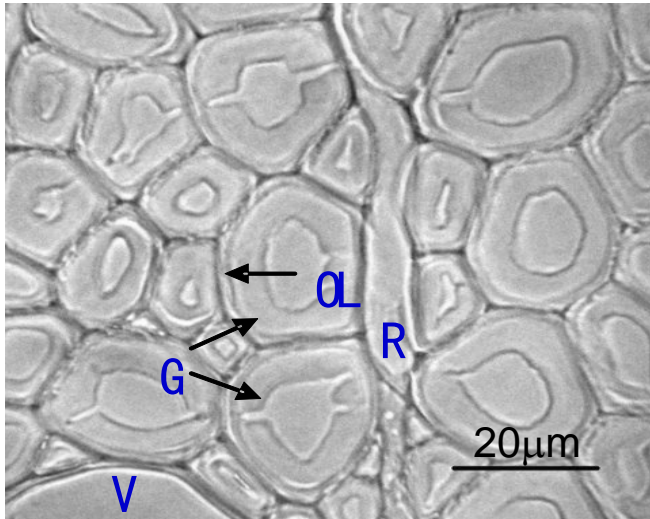
OL thickness =  $L1/2$

G-layer thickness =  $(L2-L1)/2$

Total cell wall thickness =  $L2/2$

# Shrinkage measurements at microscopic level

## → Measurements



G: G-layer; V: vessel; R: ray;

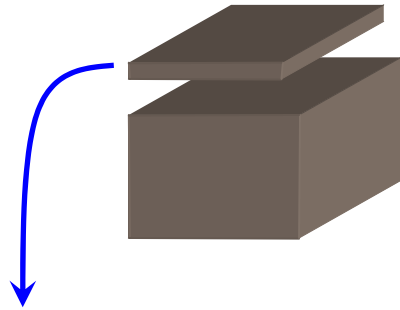
OL: Other layers including  $S_1$ ,  $S_2$  and compound lamella (CL).

Area { Lumen  
Total Cell      Perimeter { Lumen  
Total Cell

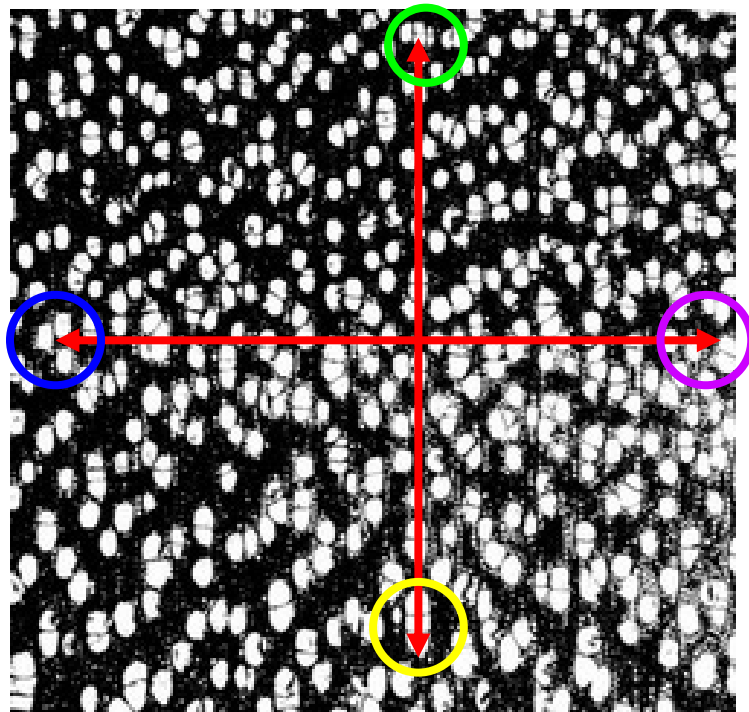
$$\text{Diameter} = 2 \times (\text{Area} / \pi)^{1/2}$$

Perimeter → Tangential shrinkage

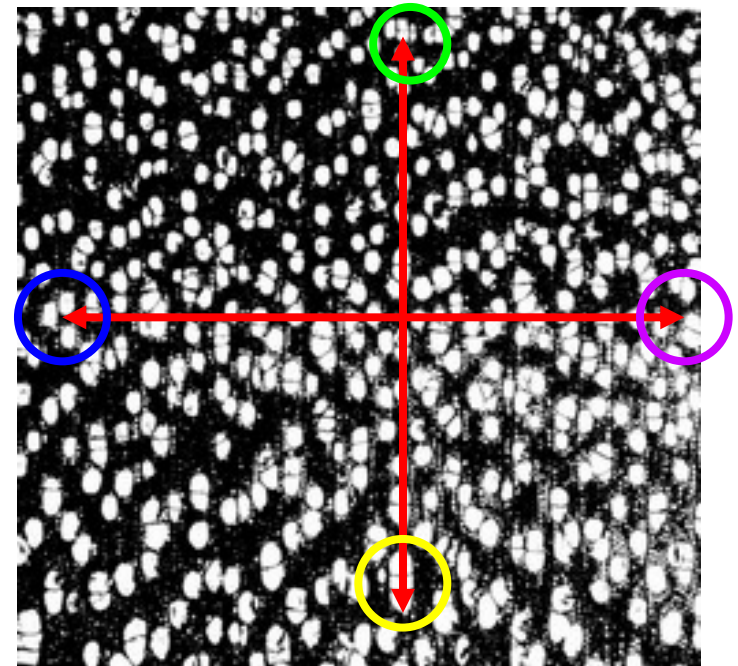
# Shrinkage measurement at mesoscopic level



Wet sample ( $7 \times 7 \text{ mm}^2$ )  
with normal sectioning



Before dried

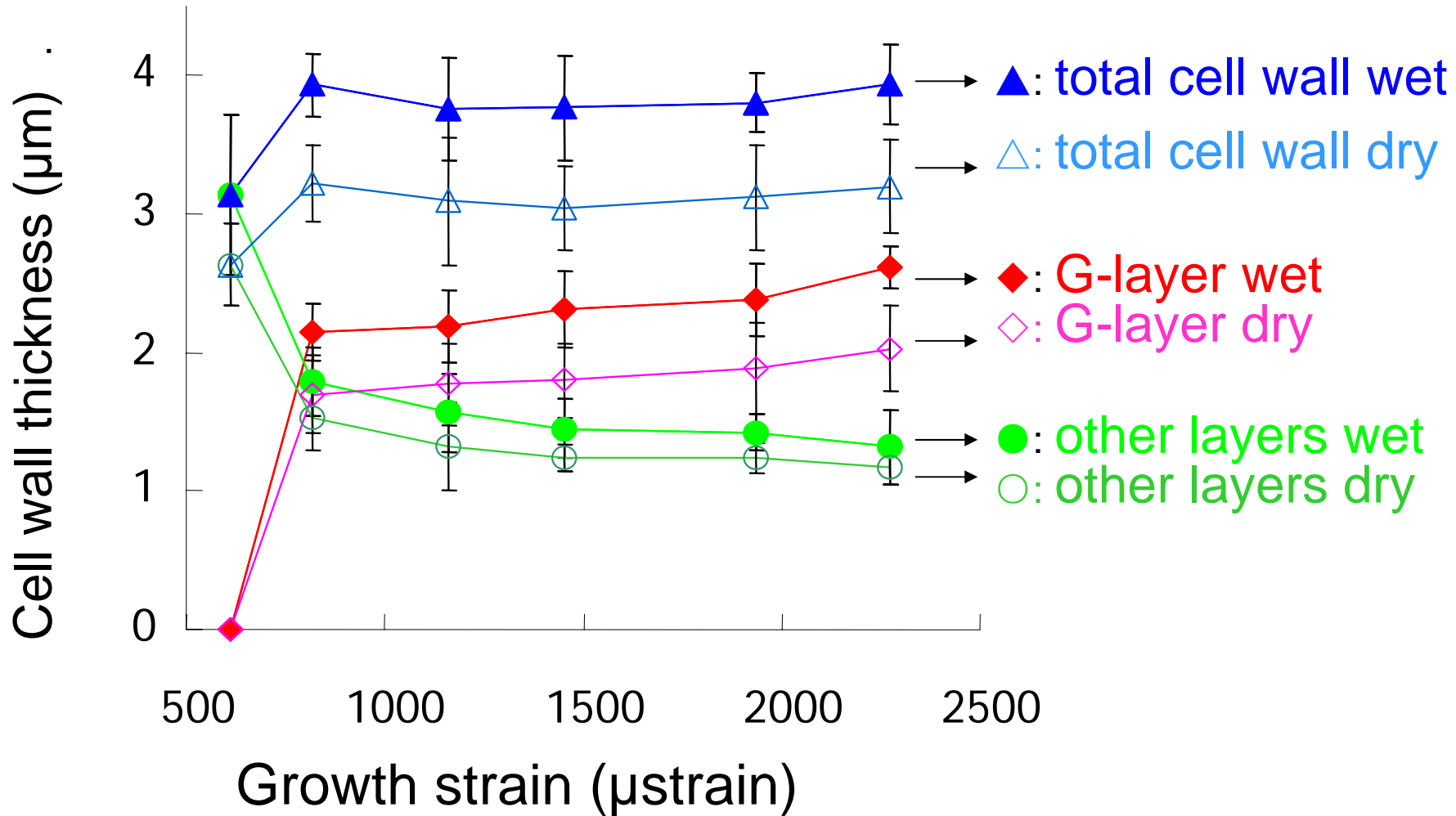


After dried

- **Results and discussion**

# Shrinkage at microscopic level

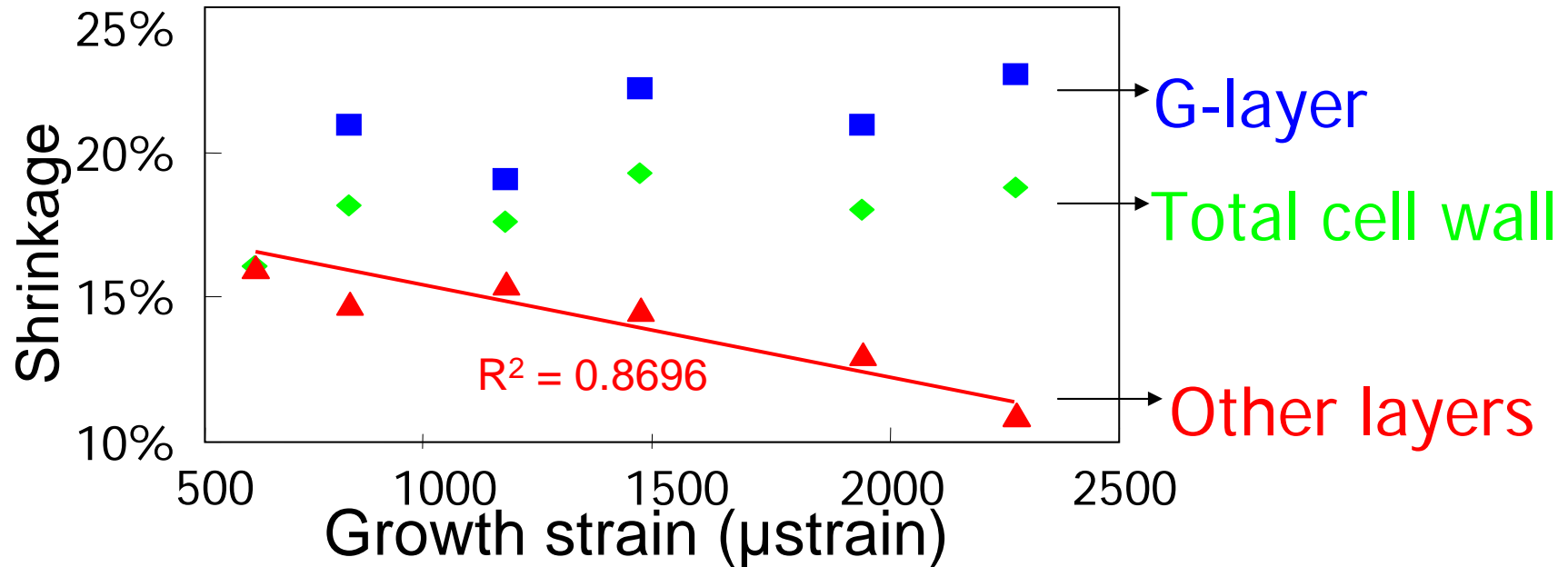
## → Cell wall thickness -GS



Error bars show the standard deviations.

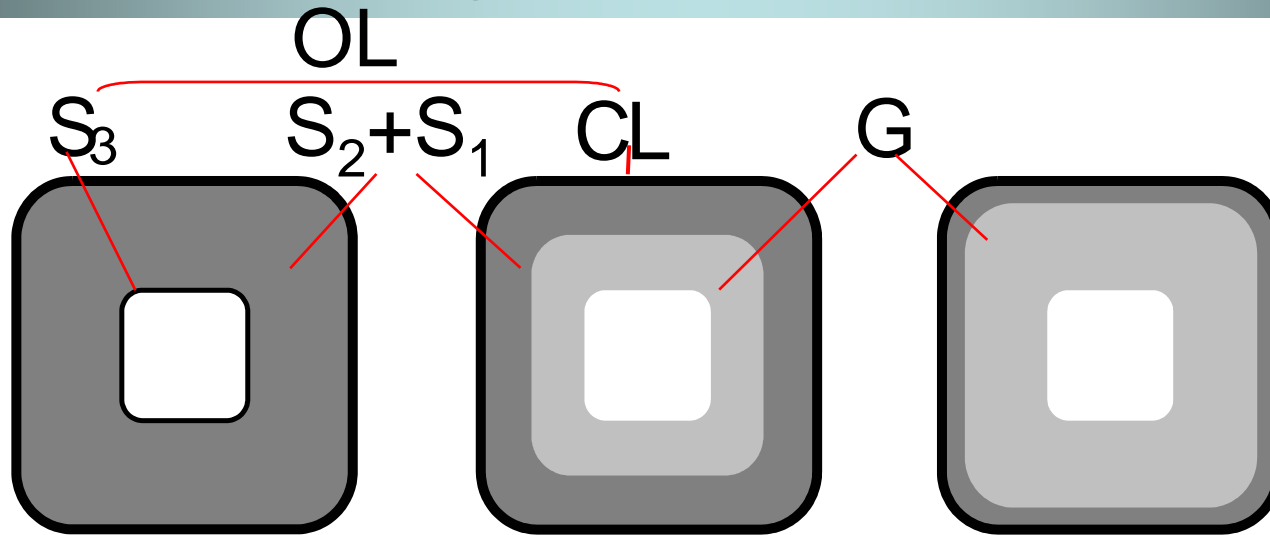
# Shrinkage at microscopic level

## → Cell wall Shrinkage -GS



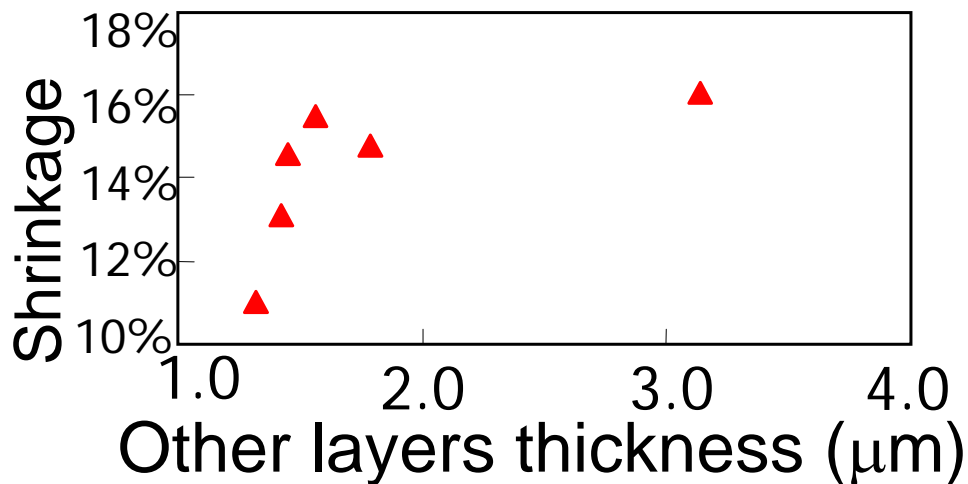
- G-layer shrinkage/GS: not significant. The structure and composition of the G-layer itself does not vary when GS increases but only G-layer thicknesses increases.
- Total cell wall shrinkage/GS: not significant, but related significantly with G-layer shrinkage. High proportion of G-layer in the cell wall can explain this phenomenon.
- The shrinkage of the OL had a very significant negative correlation with GS.

# Shrinkage at microscopic level



Proportion in  
Other layers

$S_2+S_1$  (Major role for other layers shrinkage): **Decrease**  
 $CL$  (Very low shrinkage (high lignified)): **Increase**



# Shrinkage at microscopic level

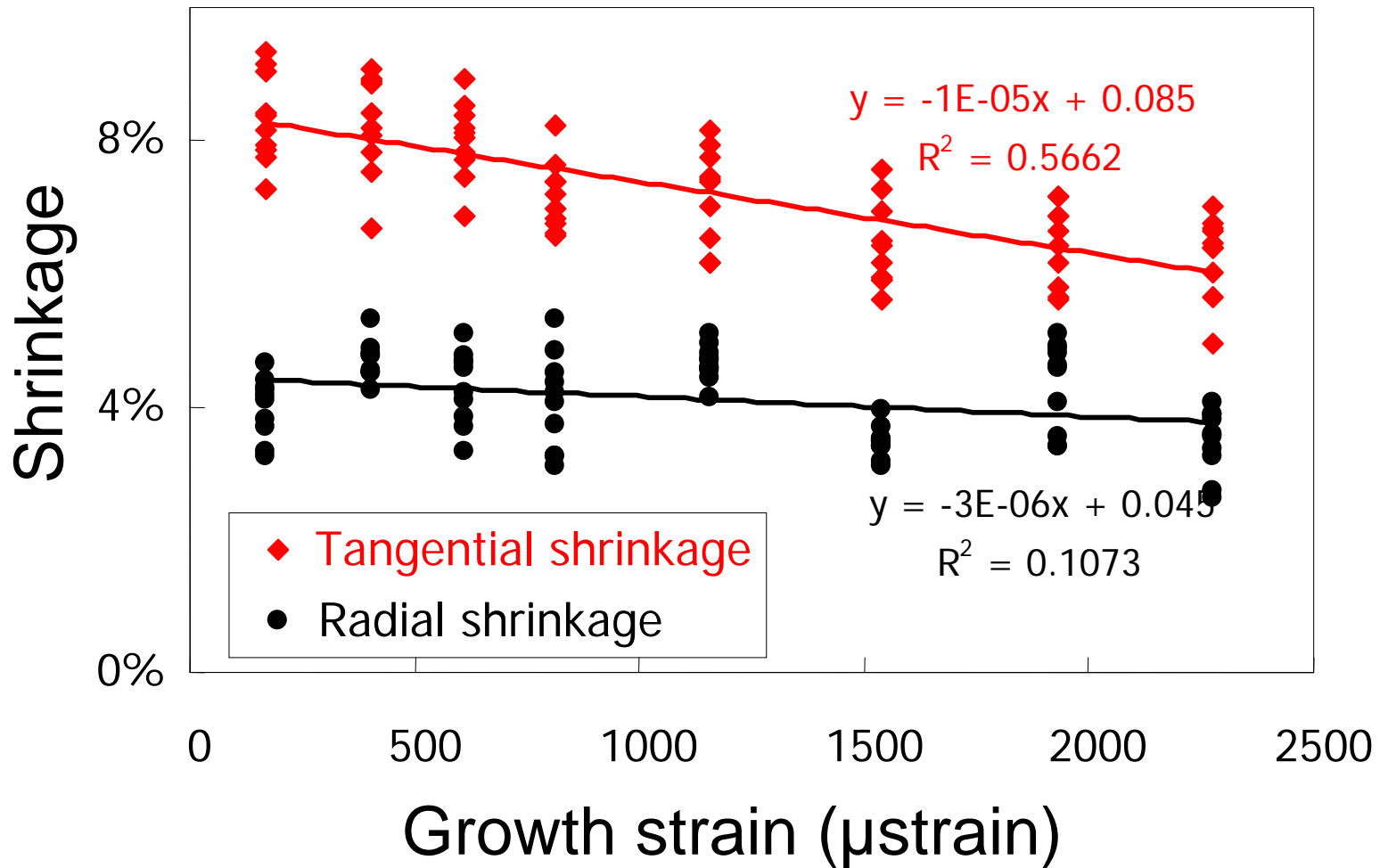
**Correlations** between parameters for the 5 samples with G-fibres except for the values marked with underline, which includes all the 6 samples. Correlation coefficients (Pearson) are given in the lower left half of the matrix and significance levels (2-tailed) in the upper right.

			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Growth strain ( $\mu\epsilon$ )			(1)	1	**	**	NS	**	**	NS	NS	<u>**</u>	<u>NS</u>
Thickness ( $\mu\text{m}$ )	Wet	G-layer	(2)	0.58	1	**	**	**	**	NS	NS	*	NS
		Other layers	(3)	-0.53	-0.42	1	**	NS	**	NS	NS	<u>NS</u>	<u>*</u>
		Total cell Wall	(4)	0.05	0.55	0.53	1	NS	NS	*	NS	<u>NS</u>	<u>*</u>
	Dry	G-layer	(5)	0.35	0.26	-0.08	0.17	1	NS	**	NS	*	NS
		Other layers	(6)	-0.47	-0.24	0.31	0.06	-0.17	1	**	NS	<u>NS</u>	<u>*</u>
		Total cell Wall	(7)	0.01	0.07	0.13	0.19	0.77	0.49	1	NS	<u>NS</u>	<u>NS</u>
e (%)	Shrinkag	G-layer	(8)	0.57	0.71	-0.50	0.48	0.57	-0.43	0.18	1	NS	*
		Other layers	(9)	<u>-0.92</u>	<u>-0.96</u>	<u>0.63</u>	<u>-0.62</u>	<u>-0.93</u>	<u>0.61</u>	<u>-0.60</u>	-0.70	1	<u>NS</u>
		Total cell wall	(10)	<u>0.64</u>	0.46	<u>-0.87</u>	<u>0.83</u>	0.32	<u>-0.87</u>	<u>0.77</u>	0.89	<u>-0.59</u>	1

NS = not significant, \* = significant at 0.05 level, \*\* = significant at 0.01 level.

# Shrinkage at mesoscopic level

Tangential and radial shrinkages -- Growth strain.



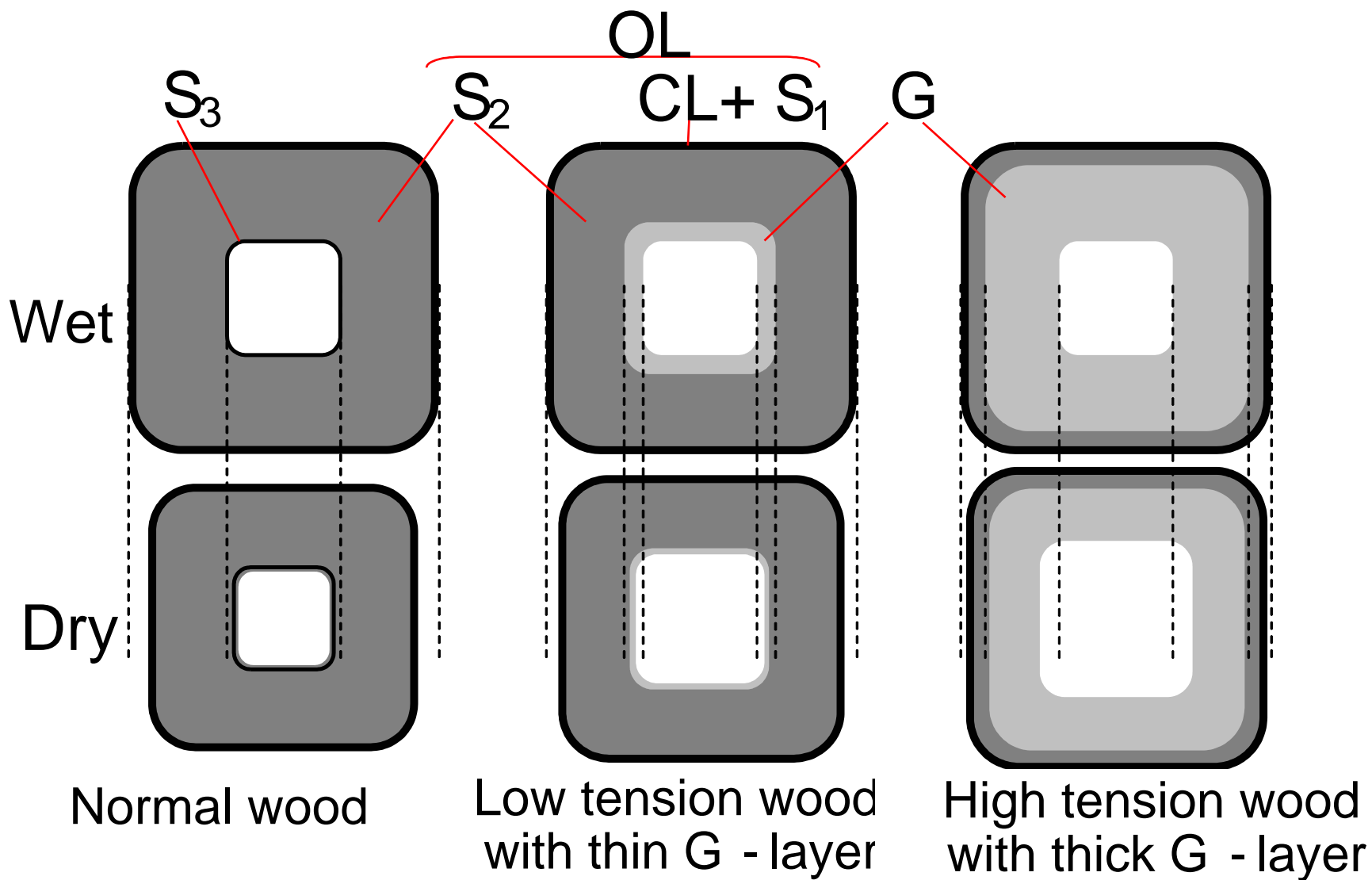
# Shrinking model of normal and tension wood cell

**?:** Considering that the lumen diameter remain nearly constant during shrinkage as in normal wood (Keylwerth, 1951 and Kelsey, 1963), G-layer shrinkage being high, it should affect in the same way the mesoscopic shrinkage (cell wall shrinks from outer to inner during drying process). **But**, we found : the thicker the G-layer, the lower the transverse shrinkage.

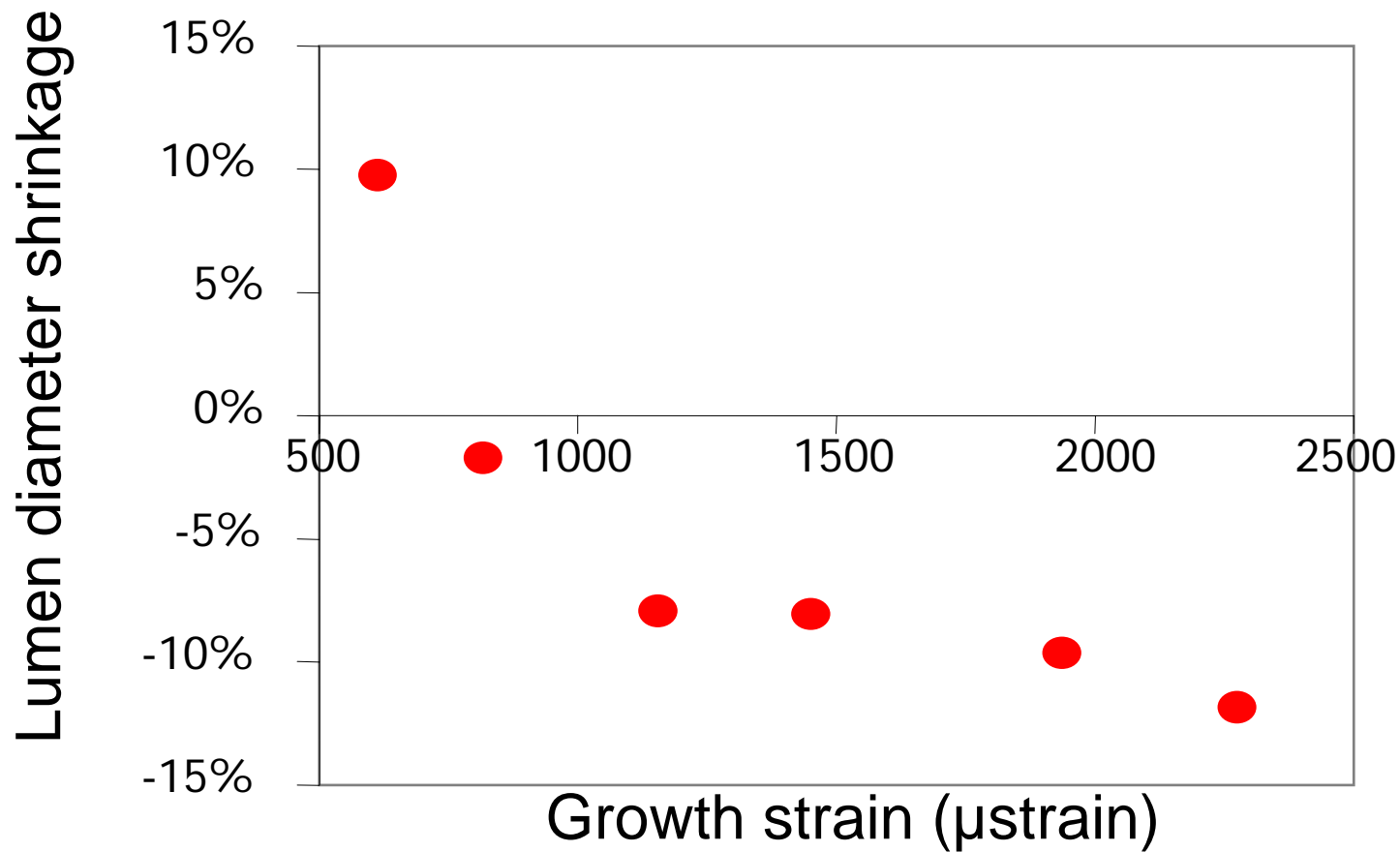
## Supposition:

In tension wood, because of the absence of the  $S_3$  layer, the G-layer shrinks from inner side to outer side during drying process. Thus, G-layer shrinkage feebly affects the total cell shrinkage. This means that the mesoscopic shrinkage is controlled by the OL shrinkage. OL shrinkage is essentially influenced by the secondary wall shrinkage: the higher GS, the thinner the secondary wall and the lower the transverse shrinkage.

# Shrinking model of normal and tension wood cell

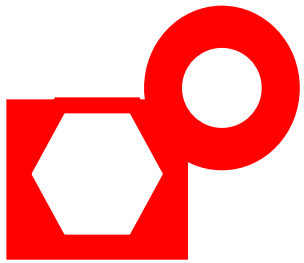


# Shrinking model of normal and tension wood cell



# • Conclusion

- The thickness of normal wood cell wall was notably less than that of the tension wood cell wall including G-layer but markedly bigger than that of the other layers excluding G-layer. In tension wood the thickness of G-layer increased with GS and the thickness of the other layers decreased with GS.
- The dry shrinkage of G-layer was significantly higher than that of the other layers. There were not significant correlations between GS and the shrinkages of G-layer and total cell. But the other layers shrinkage negatively correlated significantly with GS.
- Section tangential dry shrinkage notably higher than radial one both in normal and tension wood. Section tangential shrinkage had a significant negative correlation with GS and radial shrinkage weakly negatively correlated with GS.
- G-layer, because it did not affect the shrinkage of total cell, shrank from inner side to outer side during drying process, while the other layers, which controlled the total cell shrinkage, shrank in the contrary direction.



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*Thank you*



# Shrinkage at microscopic level

