



Roma, 21-25 settembre 2015

A novel diagnostic approach for evaluating physical properties of cellulose fibers in ancient paper

Teodonio L. (1)(2), Missori M. (3), Lojewska J. (4), Valle F. (5)

(1) Istituto Centrale per il Restauro e la Conservazione del Patrimonio Archivistico e Librario, Roma

(2) NAST, Dipartimento di Fisica, Università di Roma Tor Vergata

(3) Istituto dei Sistemi Complessi, CNR, UOS Sapienza, Roma

(4) Faculty of Chemistry, Jagiellonian University, Krakow, Poland

(5) Istituto per lo Studio dei Materiali Nanostrutturati, CNR, UOS Bologna

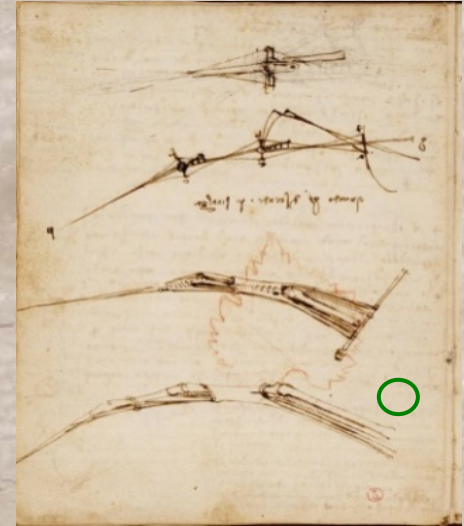


istituto
dei sistemi
complessi



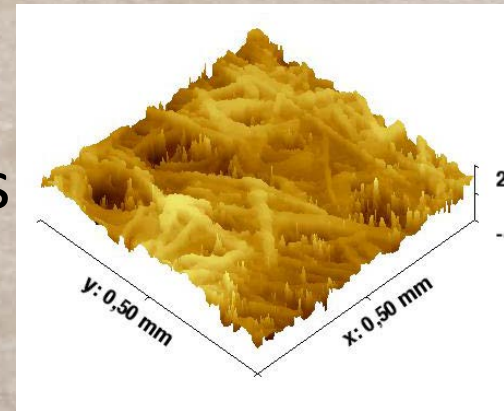
Outline

- The problem of ancient paper and its degradation

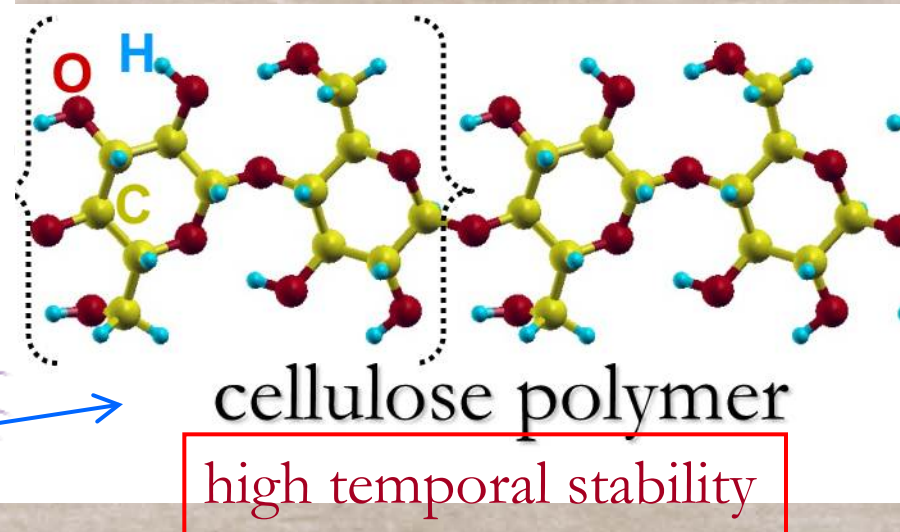
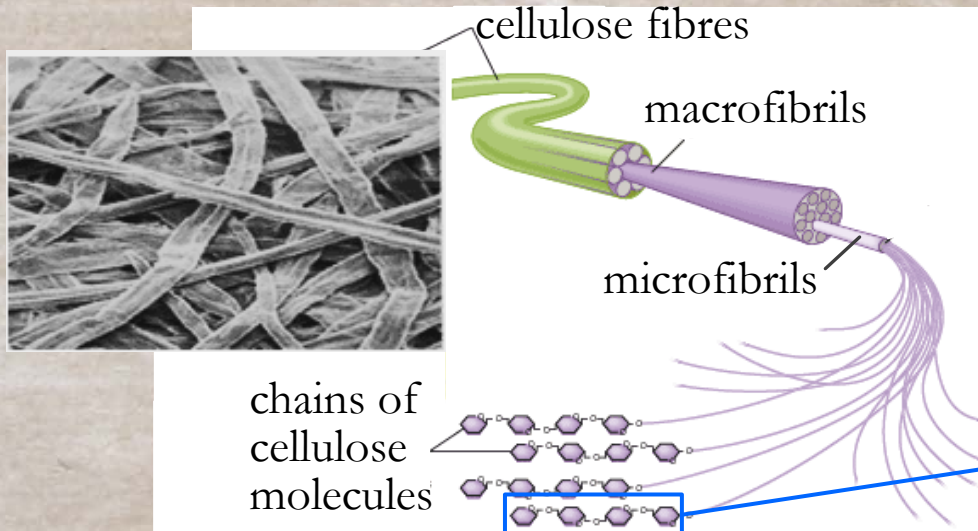
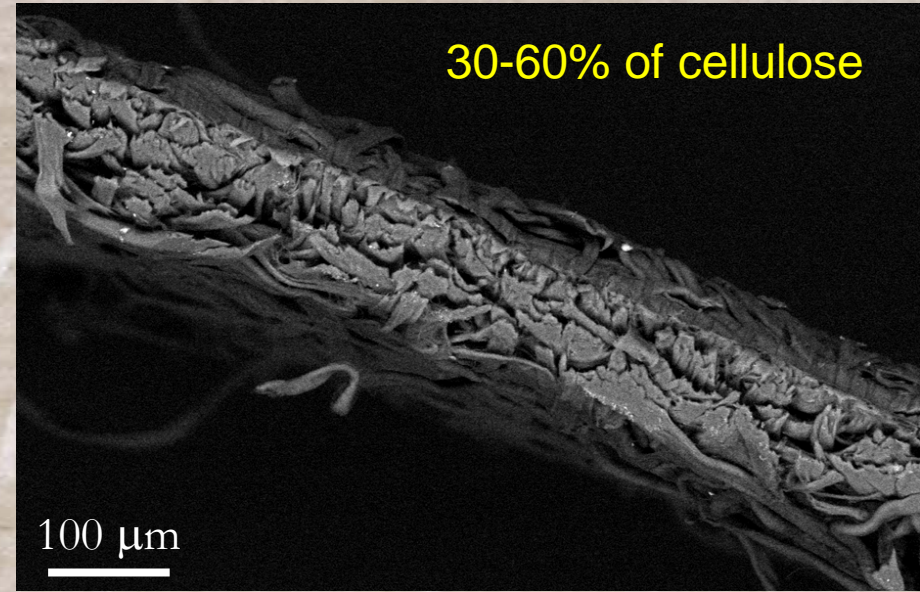
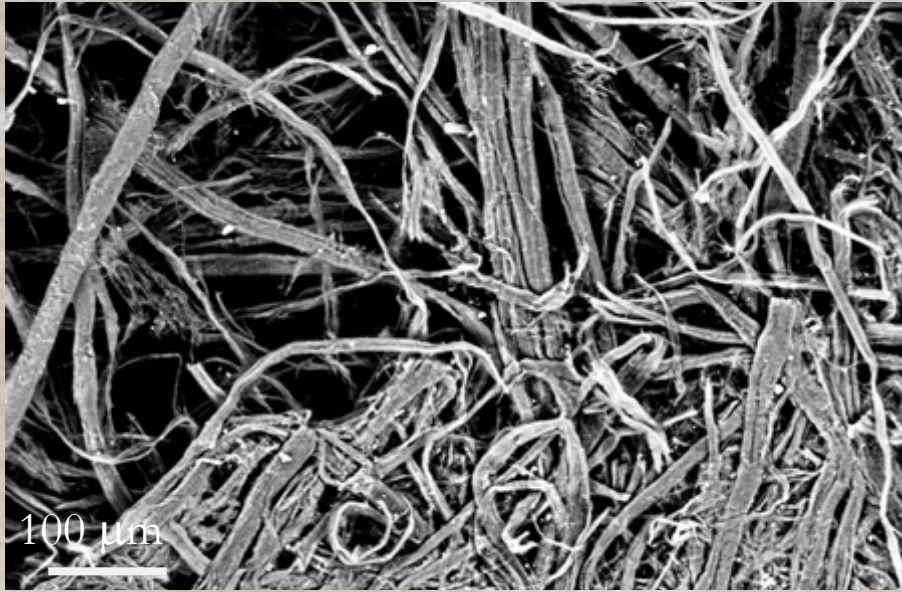


*Codex on the flight of birds
(Codice del volo) circa 1505*

- Novel non-invasive diagnostic and imaging methods:
 - Surface Profilometry
 - Atomic Force Microscopy Nanomechanics



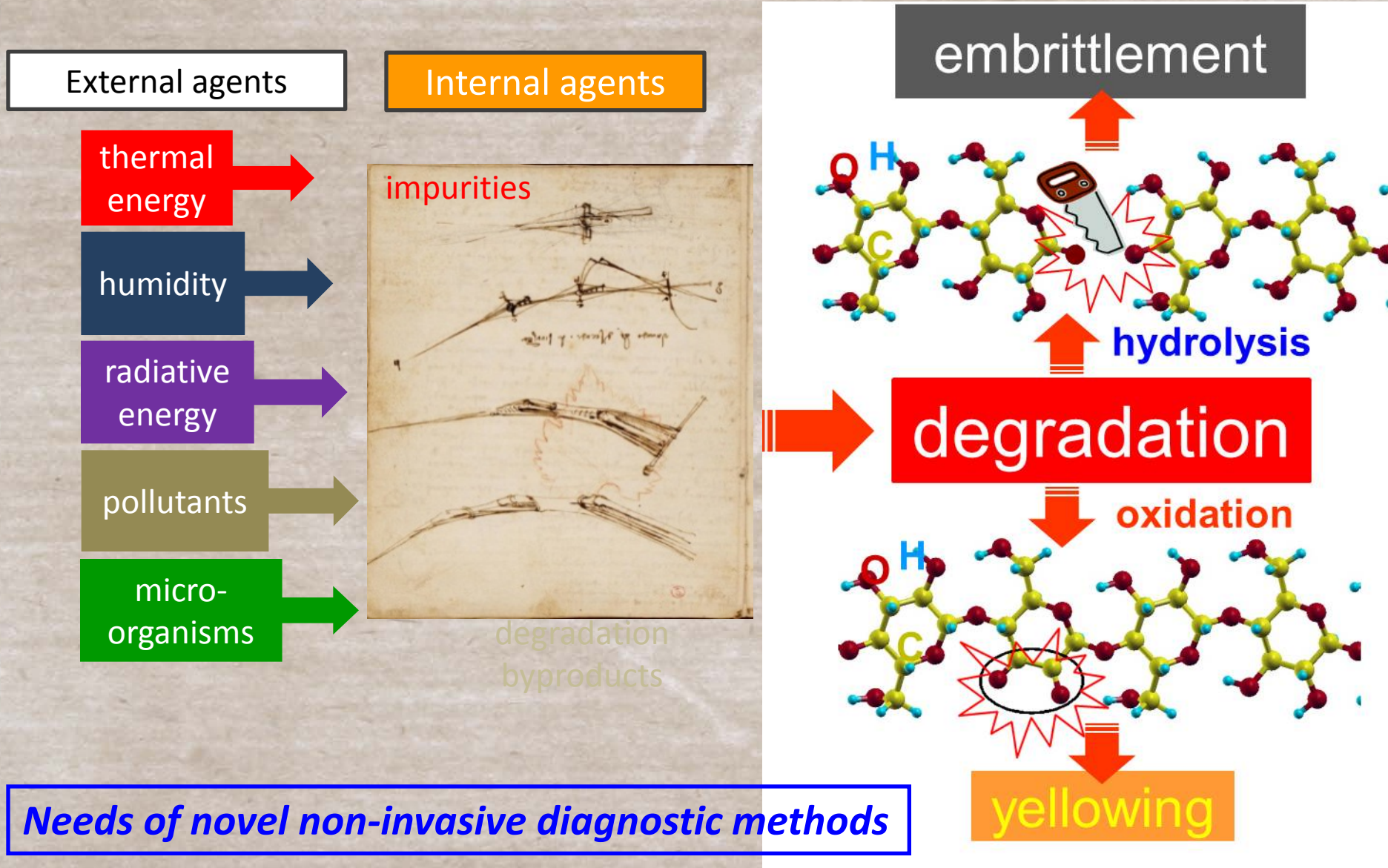
Paper: physical and chemical properties



M. Missori, et al., Phys. Rev. Lett. 97, 238001 (2006).

D. Klemm, et al., *Comprehensive Cellulose Chemistry*, Wiley-VCH Verlag, Germany (1998).

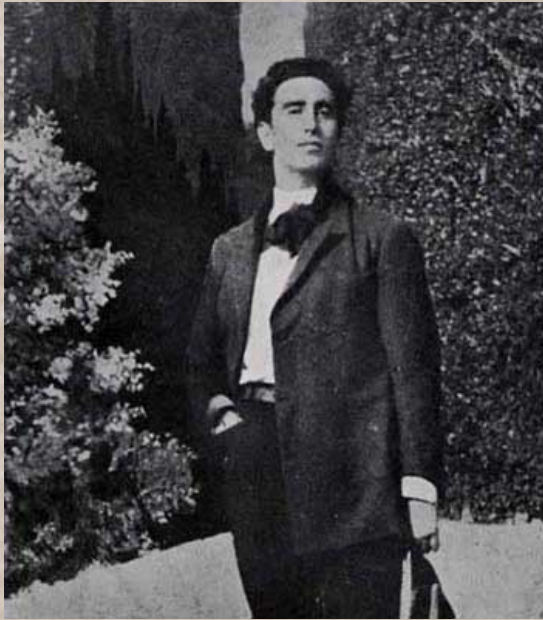
Degradation of paper on aging



L'impresa per la ...
 viene osservata e ...
 quest'impresa ... contemporaneamente
 a quest'imp. ...
 - la prima veglia ...
 alla ... la proprietà ...

...
 della ...
 qui ...
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B. Con la ...
 e quest' ...
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Carlo Maciel ...

CCI: paper sheets belonging to the Italian Minister of Cultural Heritage MiBACT

Geographical provenience	Date of use
Bologna	1470 - 1473
Unknown	1469
Bologna	1472-1495
Pescara	1442
Malcesine	1484
Casnigo Fiorano	1430 - 1448
Strozza	1466 - 1529
Piacenza	1431 - 1482
Pola	1441 - 1446
Gaeta	1480



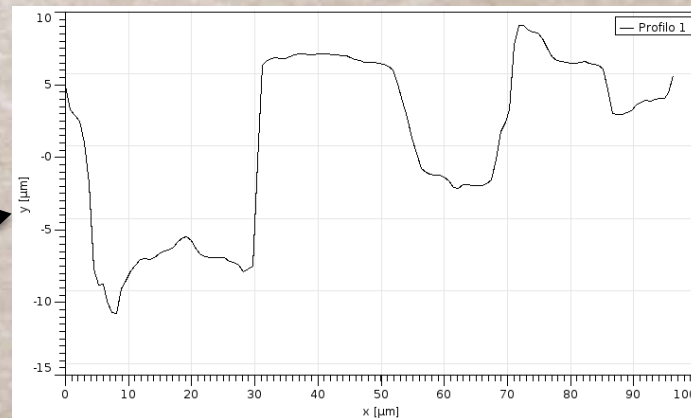
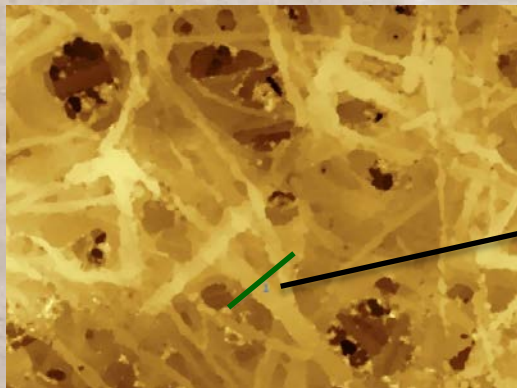
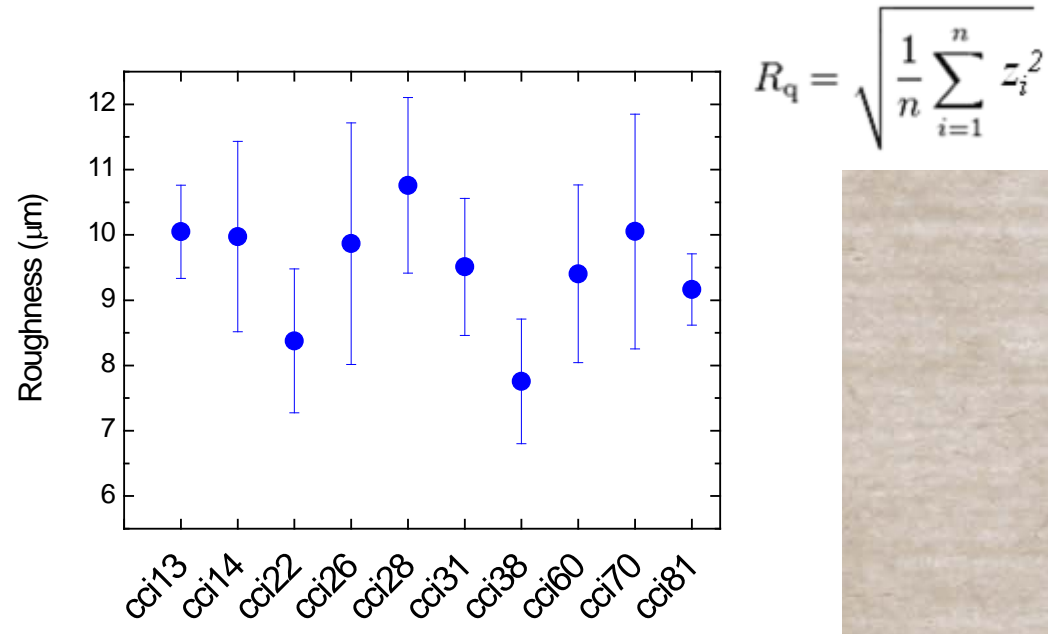
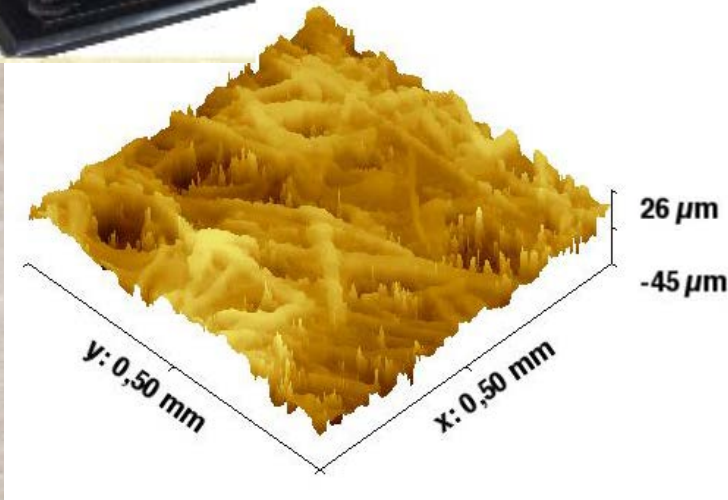


SmartWLI with Nikon
interferometric
objectives

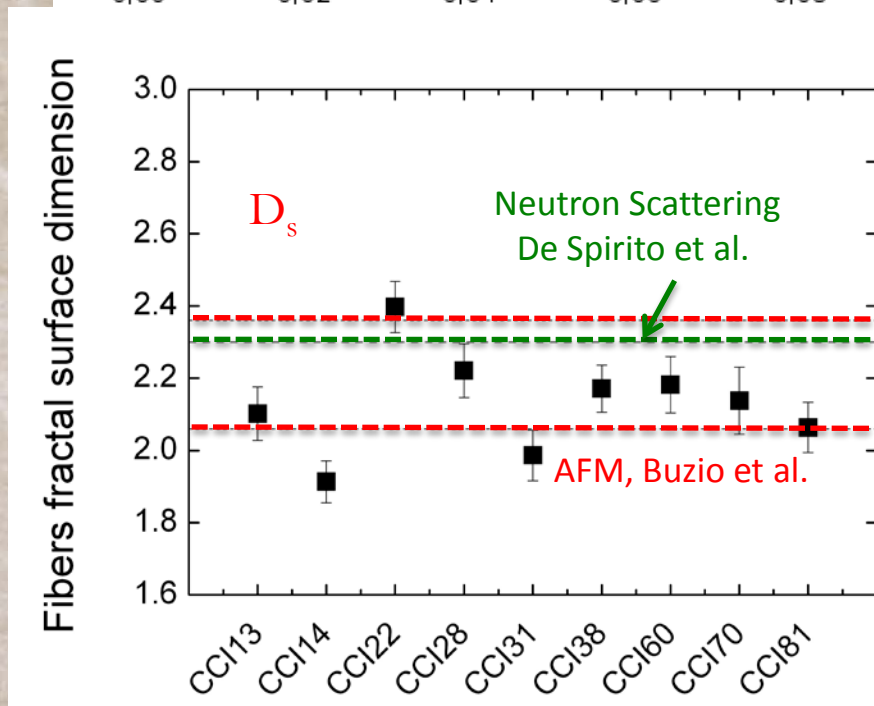
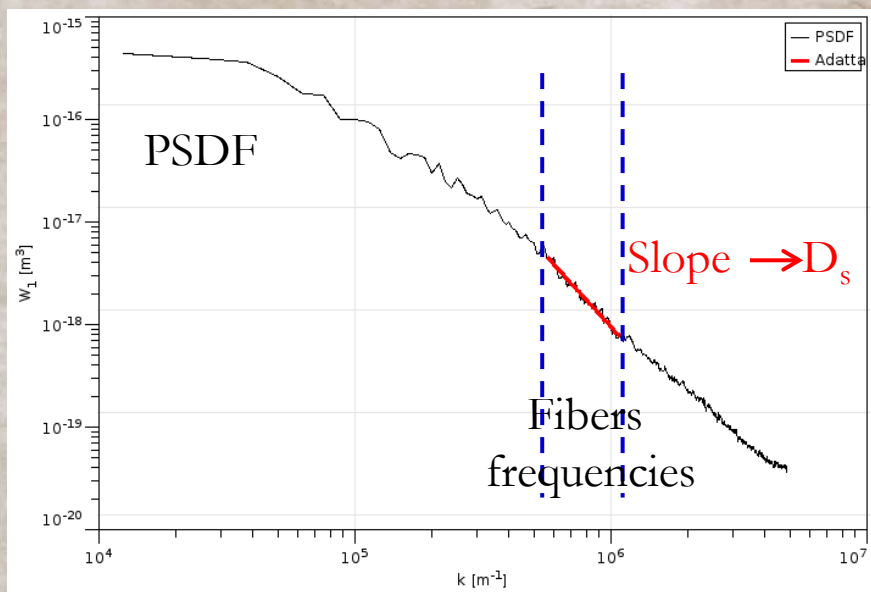
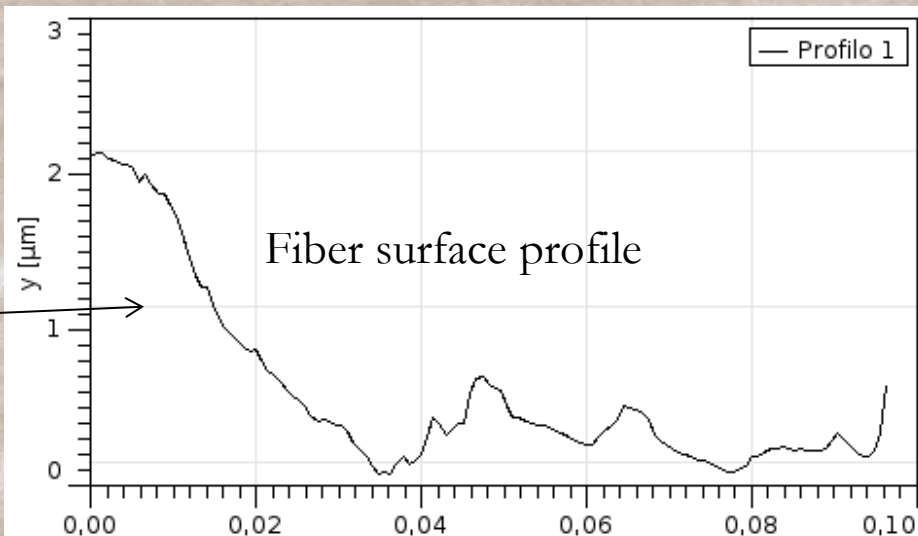
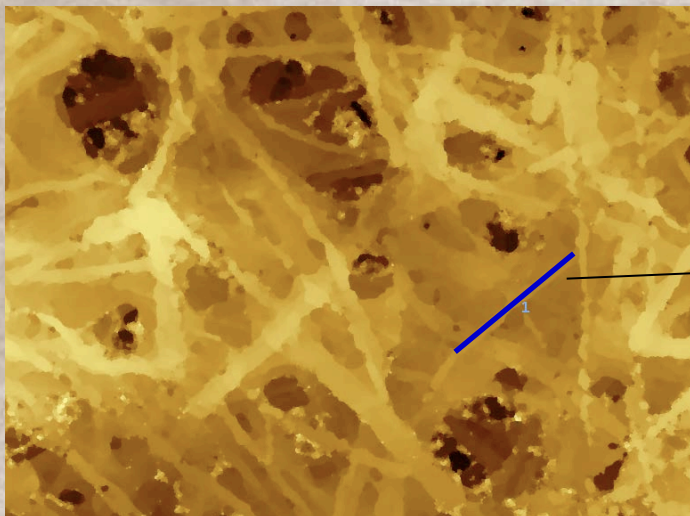
Real 3D topography
x,y : optical resolution
z : nm scale

Micrometer scale morphology: white light optical profilometry

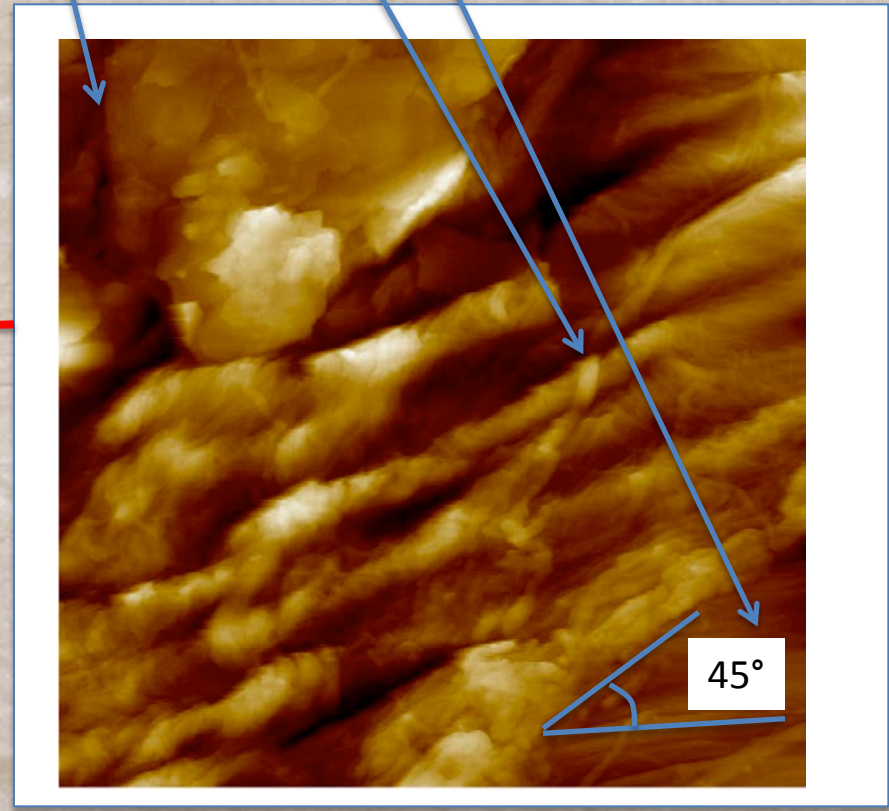
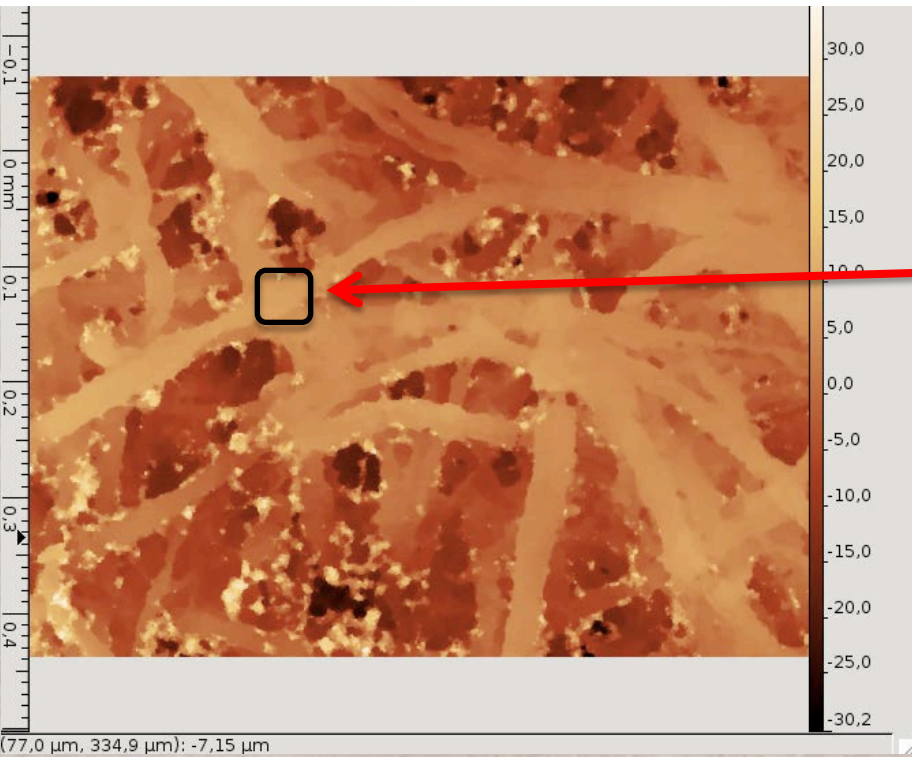
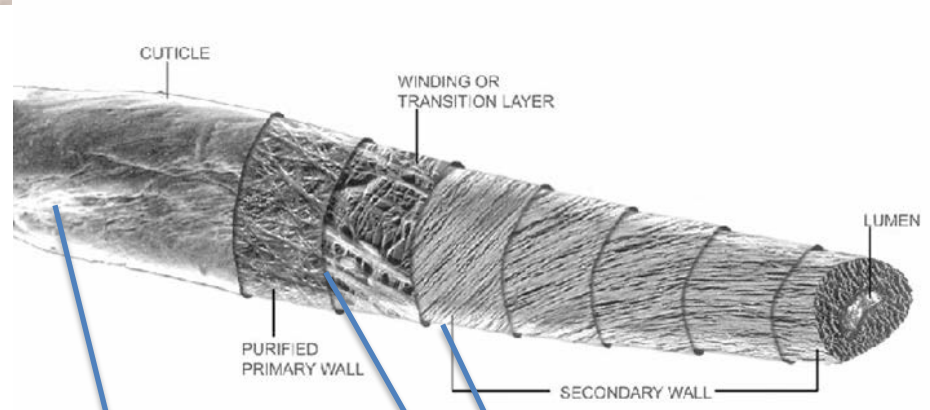
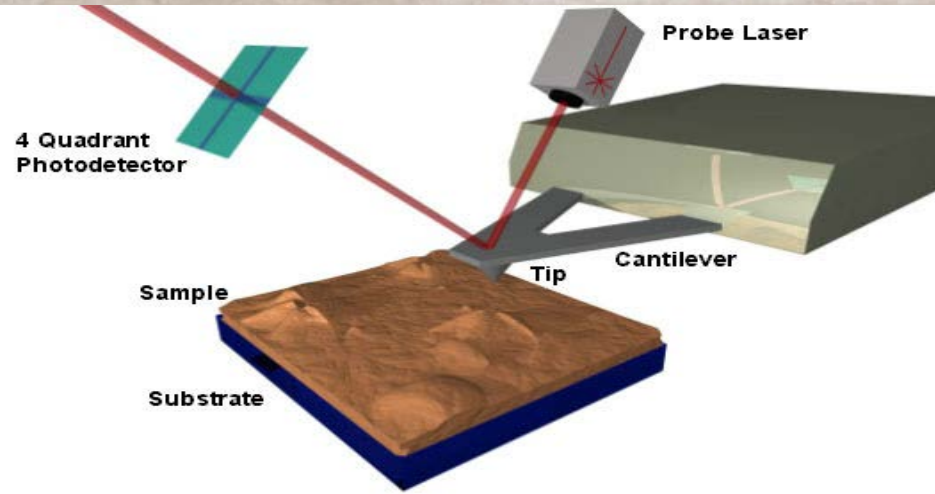
Non-invasive measurement
of the roughness of the
sheets



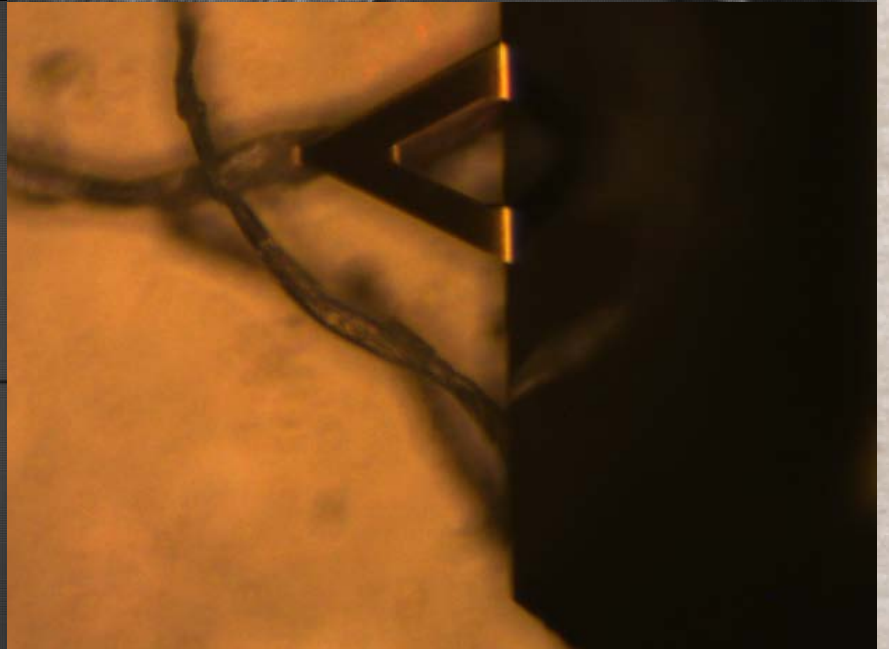
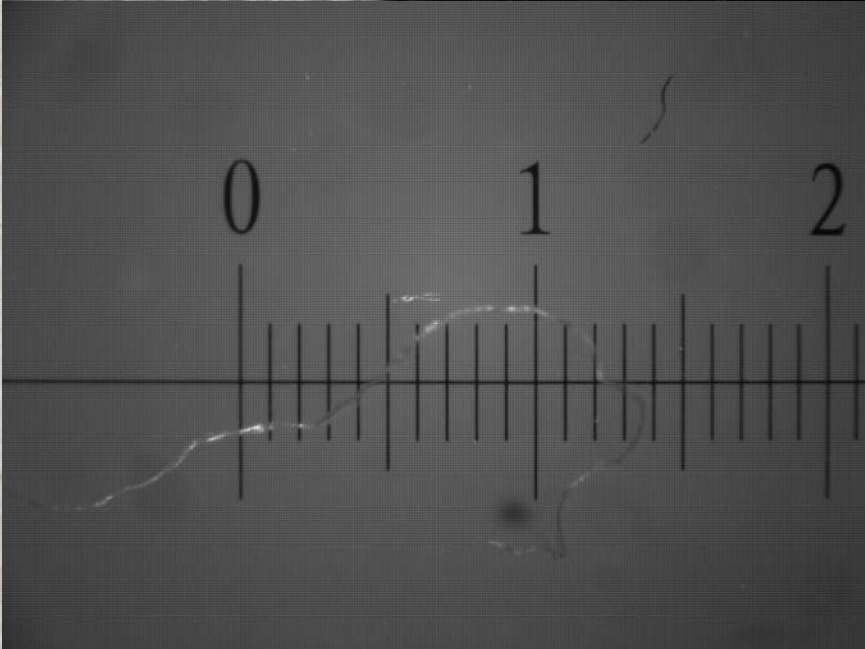
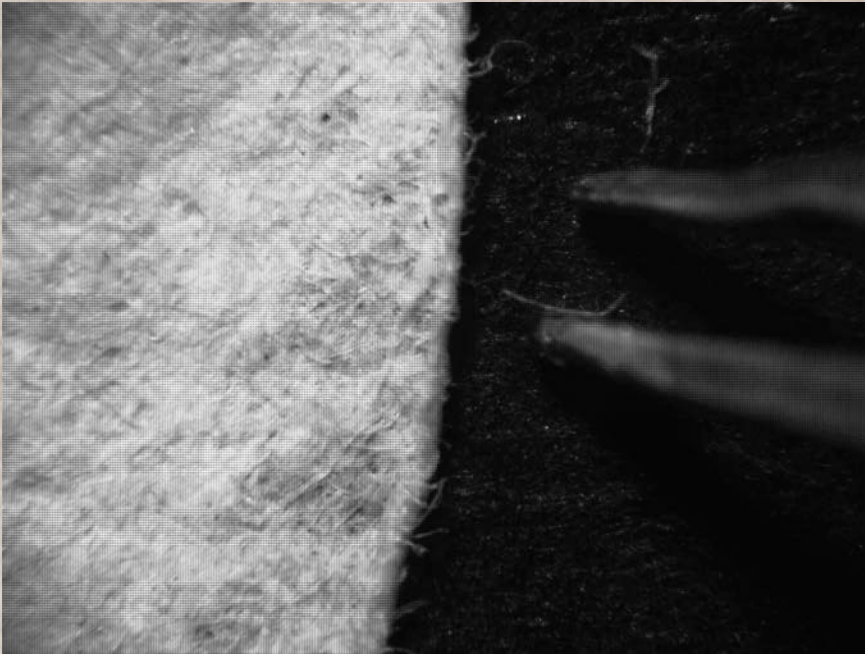
Non-invasive measurement of the fiber's fractal dimension



From Micro to **Nano**-scale morphology: Atomic Force Microscopy as an imaging tool

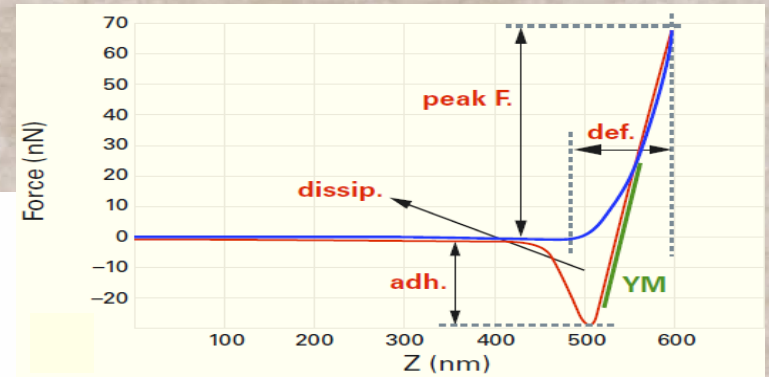
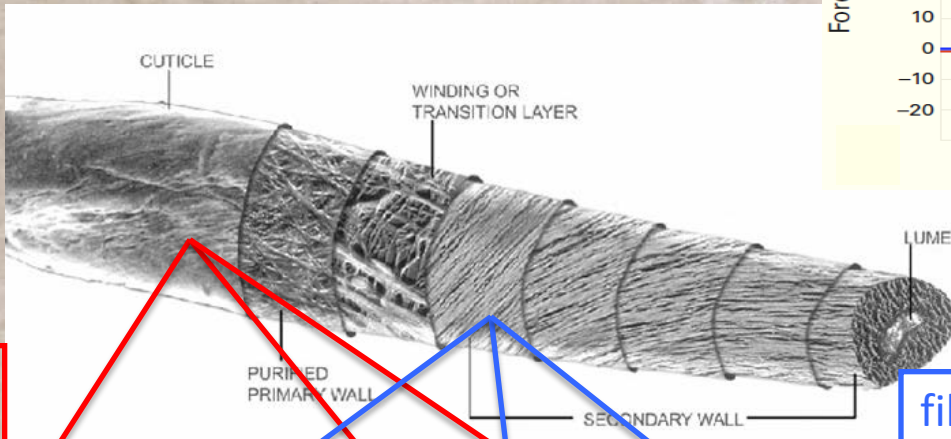


Sample preparation



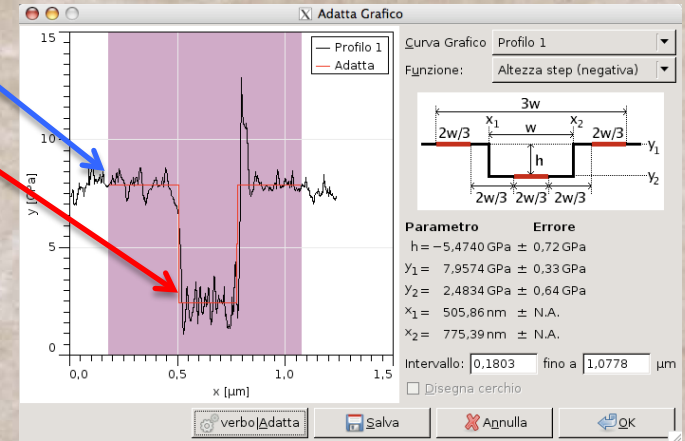
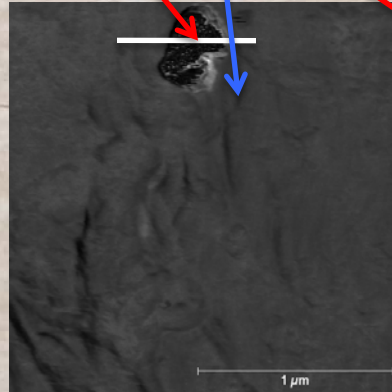
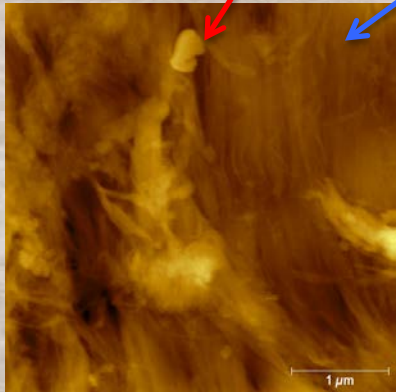
Quantitative Nanomechanics: Atomic Force Microscopy

...going beyond simple imaging



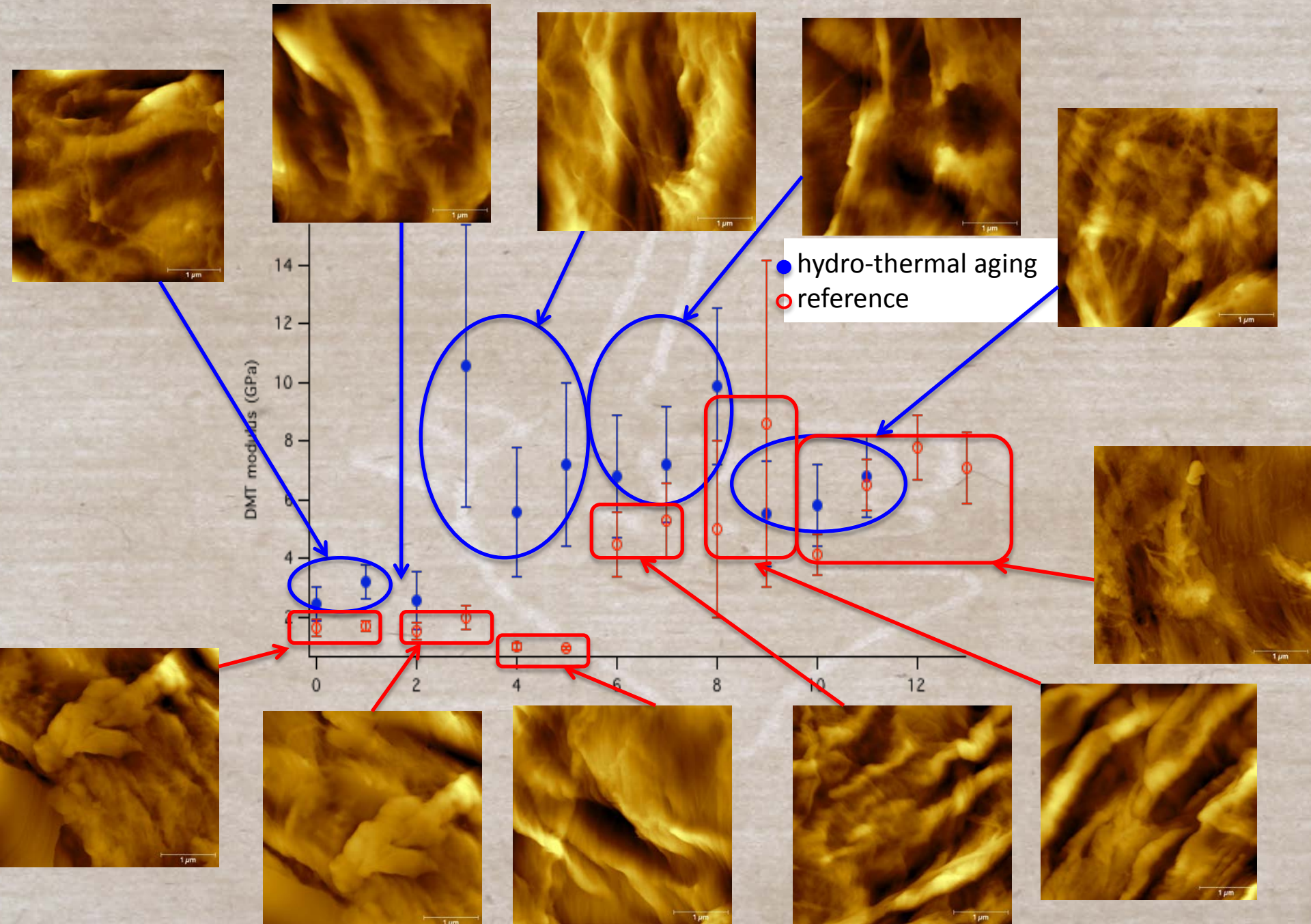
cuticle softer

fibers stiffer

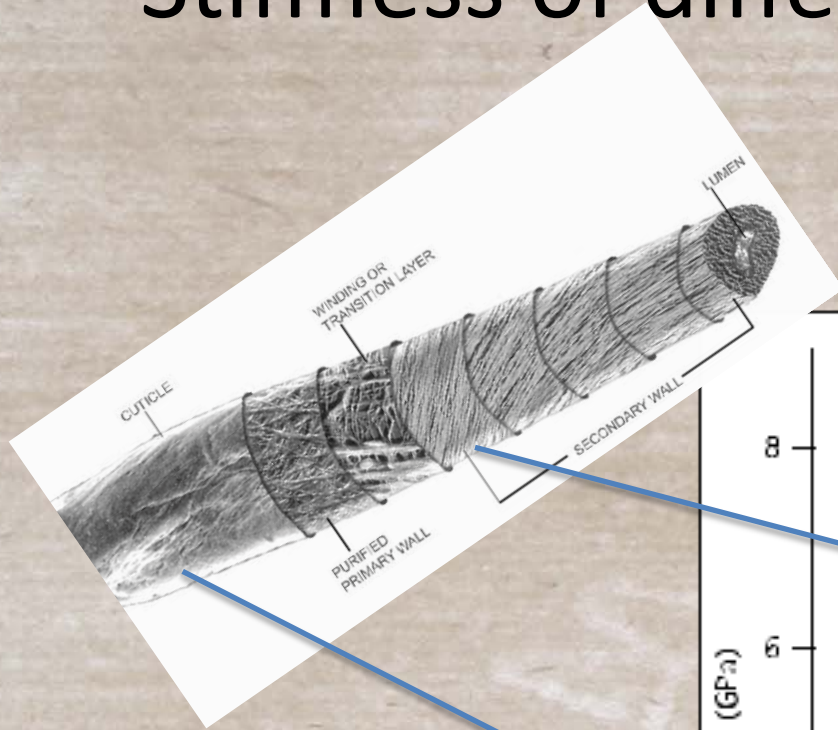


Different cellulose areas → different mechanical properties
correlating nm scale topography with mechanics

Nanomechanical properties of different polymer arrangement: the aging effect

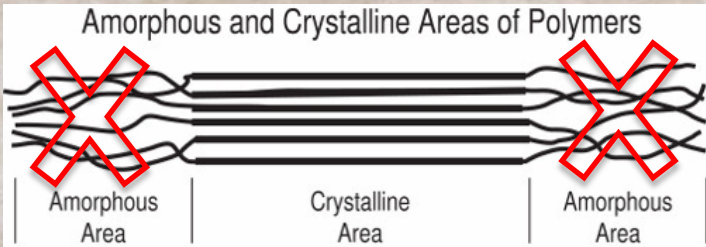
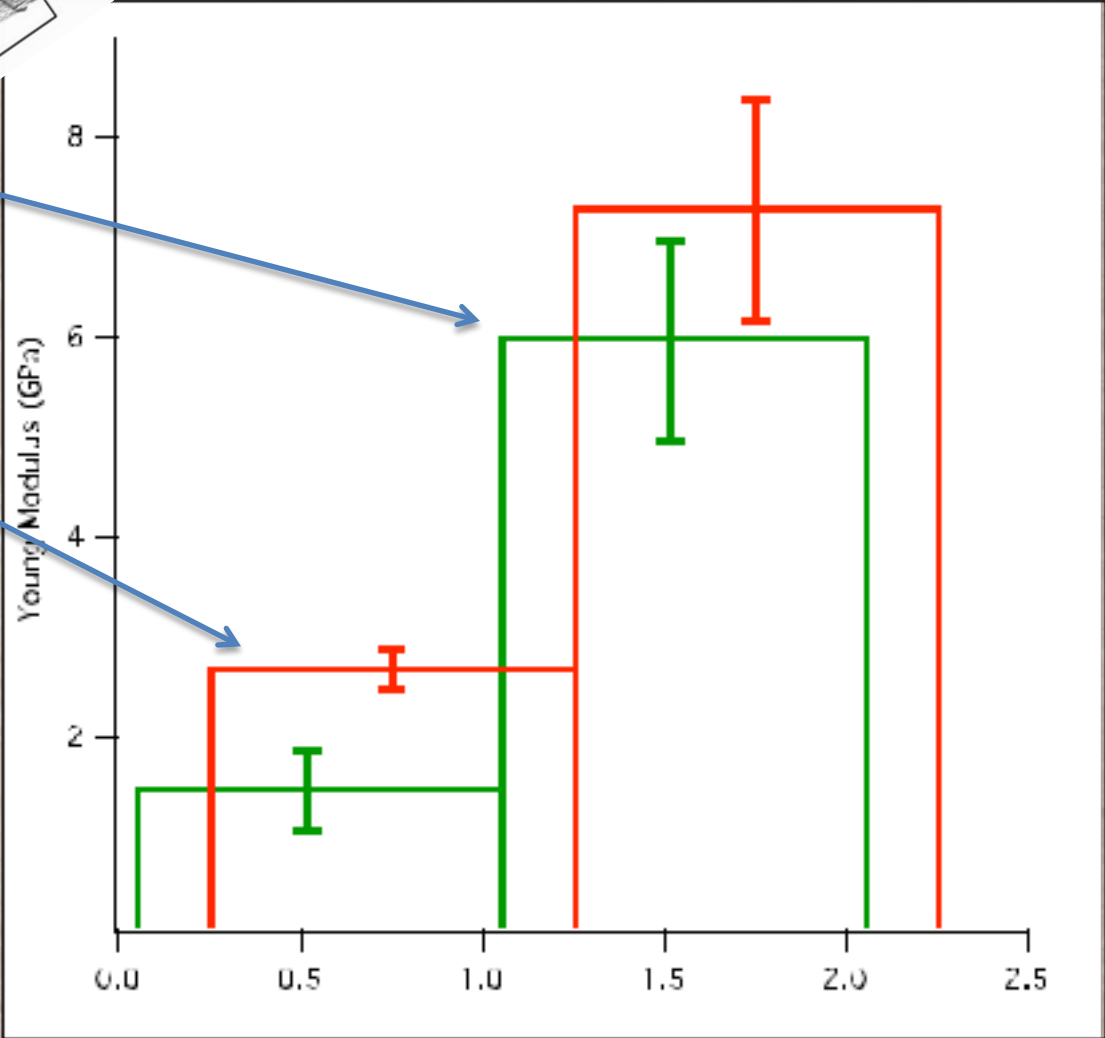


Stiffness of different areas compared



reference
paper

artificially aged paper
48 days 150°C



Modeling could improve
our diagnostic method



Francesco Valle

Thanks



Alessio Nubile
MIST E-R



Joanna Lojewska



Paolo Bariani
Nanoscale
Measurement
Instrumentation
at Schaefer-Tec