

Enhancing the accessibility of surface polymers to enzymes in raw cotton fabric by plasma pretreatment

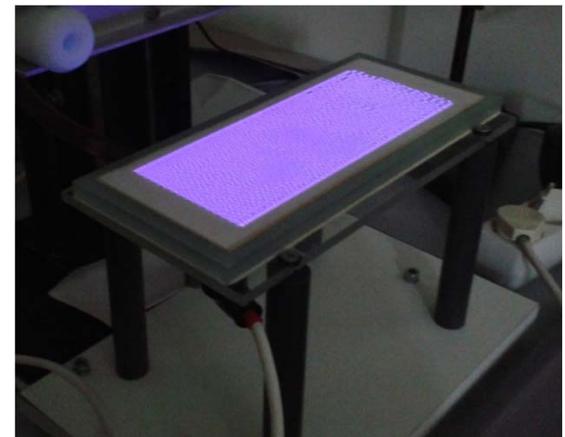
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Non-thermal plasma treatment

Activation and modification of surface layers without alteration of the bulk characteristics



diffuse coplanar
surface barrier discharge

Non-thermal plasma treatment

Textiles

For cellulosic fibres and fabrics:

- etching and partial removal of the surface layers of yarns (i.e. starch size) and fibres (waxy materials)
 - increase in hydrophilicity
 - increase in efficiency of the traditional chemical and enzyme-aided processes

Aims: evaluation of the effect of plasma

- on the efficiency of the subsequently applied enzyme process
- the accessibility of polymers i.e. respective substrates for the enzymes

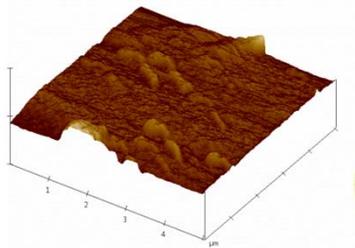
Experimental

- Raw cotton fabric
- Plasma treatment: for 30, 90 and 180 s.
- Analysis of surface properties:
 - roughness*: AFM,
 - chemical composition*: FT-IR ATM and XPS
 - hydrophilicity*: contact angle, wetting time
- Analysis of bulk properties:
 - tensile strength and elongation*
 - pectin content*: Ruthenium red dyeing
 - desizing efficiency*: Tegewa blue scale
- Accessibility of amylase and cellulase enzymes:
 - measurement of the *reducing sugars* liberated

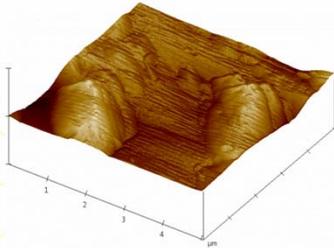
Results

Surface properties

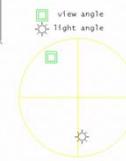
Deep “pits” with a depth of 215 nm



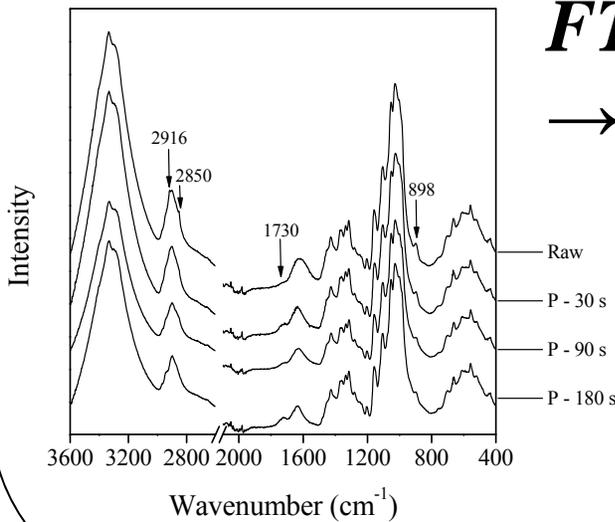
untreated



plasma treated



→ etching the sizing layer
 → localized ablation of the waxy layer

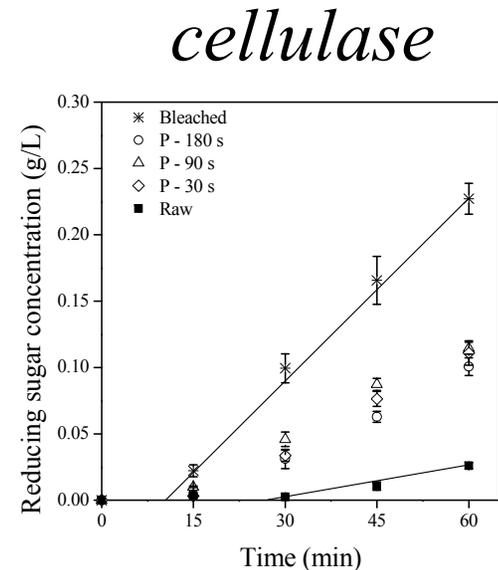
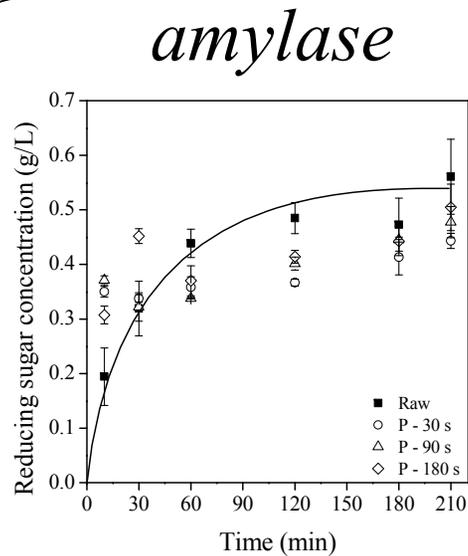


FT-IR: Partial removal of the waxy layer
 → *exposure of cellulose and pectin*

XPS: increase in O/C ratio
 increase in oxidized states of C
 → *bond scission and oxidation of starch*
 → *exposure of cellulose, pectin*

Results

Reducing sugars liberated by



- More efficient solubilization of starch in the first 10 minutes
- Removal of 10-20 % of starch size by air-plasma treatment
- A dramatic increase in the rate of cellulose hydrolysis

Cellulose and starch became → *more accessible*
 → *more open* to contact with enzymes

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INTRODUCTION

By using non-thermal plasma treatment, the surface layers of the fibrous substrates can be activated and modified without alteration of the bulk characteristics. Plasma treatment is effective on the surface up to the depth of about 200 nm and can affect the removal of both the sizing agent and waxy surface layer. Furthermore, plasma pretreatment can increase the efficiency of the enzyme-aided textile processes by accelerating the enzyme action. In this presentation, besides characterizing the changes in surface properties of raw cotton by a couple of simple tests and powerful techniques as a function of time of cold plasma treatment, the enhancement in accessibility of enzymes to polymers such as starch and cellulose located on the surface of the fibers was also characterized.

EXPERIMENTAL

Raw cotton : plain-weave, with a fabric weight per unit area of 153 g/m²

Non-thermal plasma treatment:

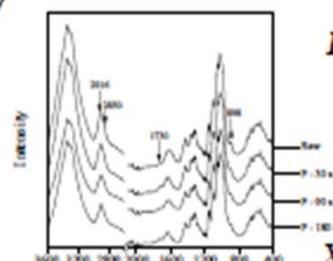
In ambient air by diffuse coplanar surface barrier discharge type equipment, applying a power of 300 W and treatment times of 30, 90 and 180 s.



Surface accessibility :

To amylase and cellulase enzymes before and after the plasma treatment, characterised by measuring the reducing sugars liberated during the enzymatic hydrolysis.

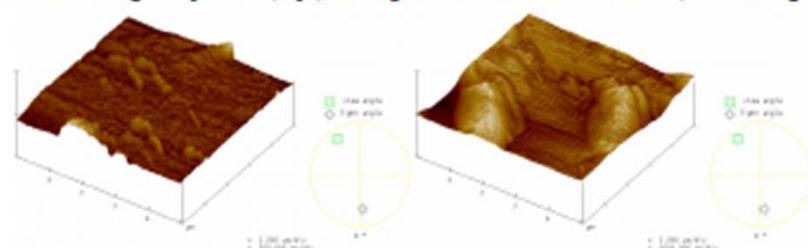
RESULTS AND DISCUSSION



FT-IR ATR: partial removal of the waxy outer layer by plasma
→ exposure of cellulose and pectin

XPS: increase in O/C ratio and concentration

AFM images of raw (left) and plasma-treated cotton (180 s, right)



Conclusions

- Plasma slightly destroyed and oxidized the *starch size* on the surface of warp yarns and partially removed the *waxy coverage* of the cotton fibers in the weft yarns, resulting in a more *hydrophilic surface*.
- Plasma etching of the surface contributed to the *exposure of polymers such as pectin and cellulose* located under the waxy outer layer of the fibers.
- The increased accessibility of the respective substrates to amylase and cellulase enzymes resulted in *a dramatic increase in the rate of starch and cellulose hydrolysis*, respectively.
- Owing to the *faster enzyme reactions*, the enzymatic treatment time can be shortened sharply.
- Tensile properties are unaffected by the applied plasma treatment.