HYBRID ORGANIC-INORGANIC FINISHING FOR MULTIFUNCTIONAL TEXTILES

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PRESENTATION OUTLINE

1 Introduction

2 Material and method

3 Results and discussion

4 Conclusion

Where is innovation in textile finishing
What is the sol gel process
Why hybrid structure finishing

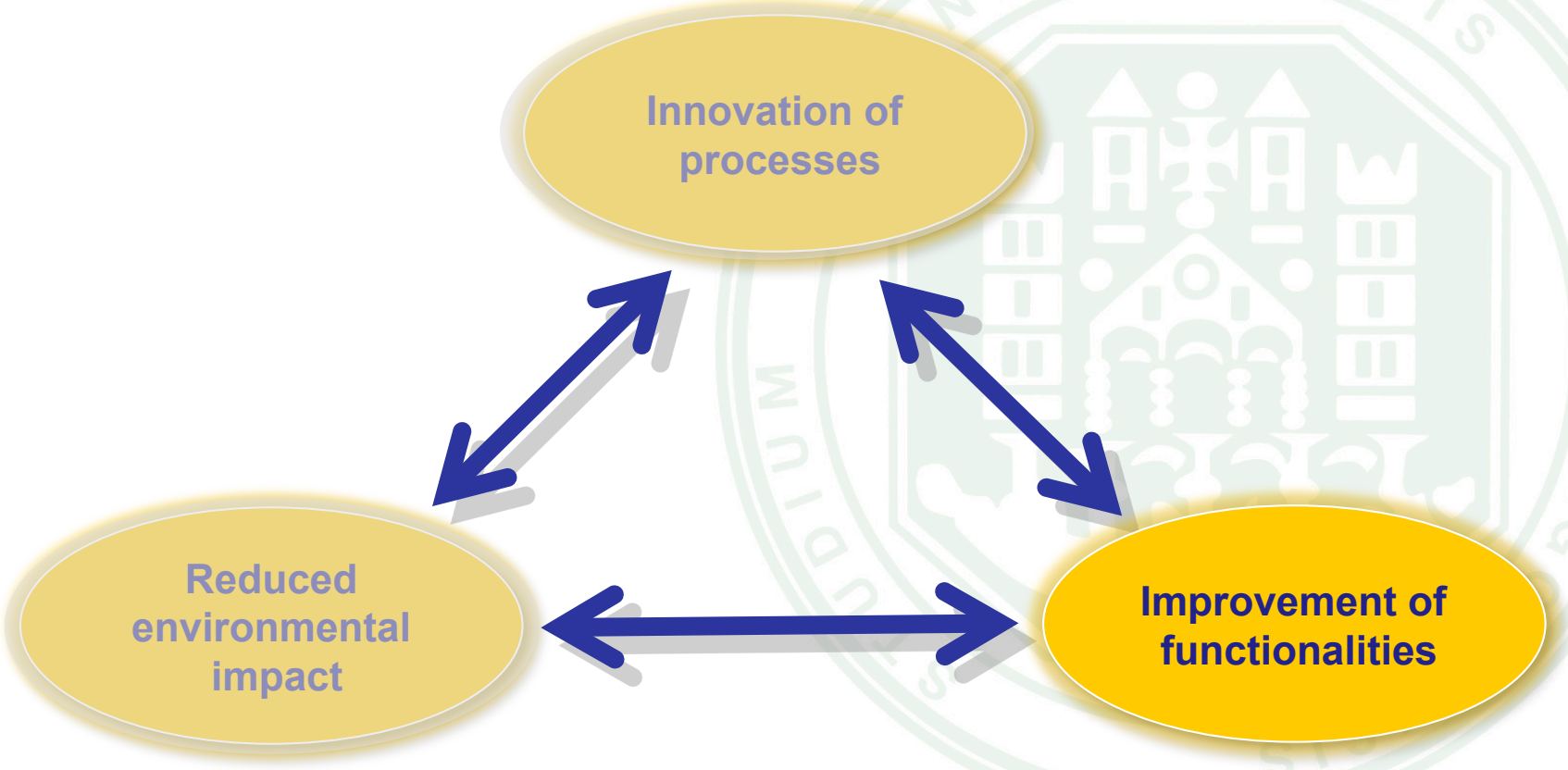
CHEMICALS IN TEXTILE FINISHING

Finishing is the final series of operations that produces finished textile fabric from greige goods.

- ✓ Chemicals (active products, catalysts, auxiliaries) usually are different for each textile finishing;
- ✓ Treatments are not always mutually compatible and require large amounts of thermal energy for water heating and drying;
- ✓ The processes can negatively affect the textile substrate (dpi, tensile strength, hand, etc.);
- ✓ Chemicals usually have a high environmental impact;
- ✓ High ratio: applied quantity / performance achieved.

TEXTILE FINISHING: Research items

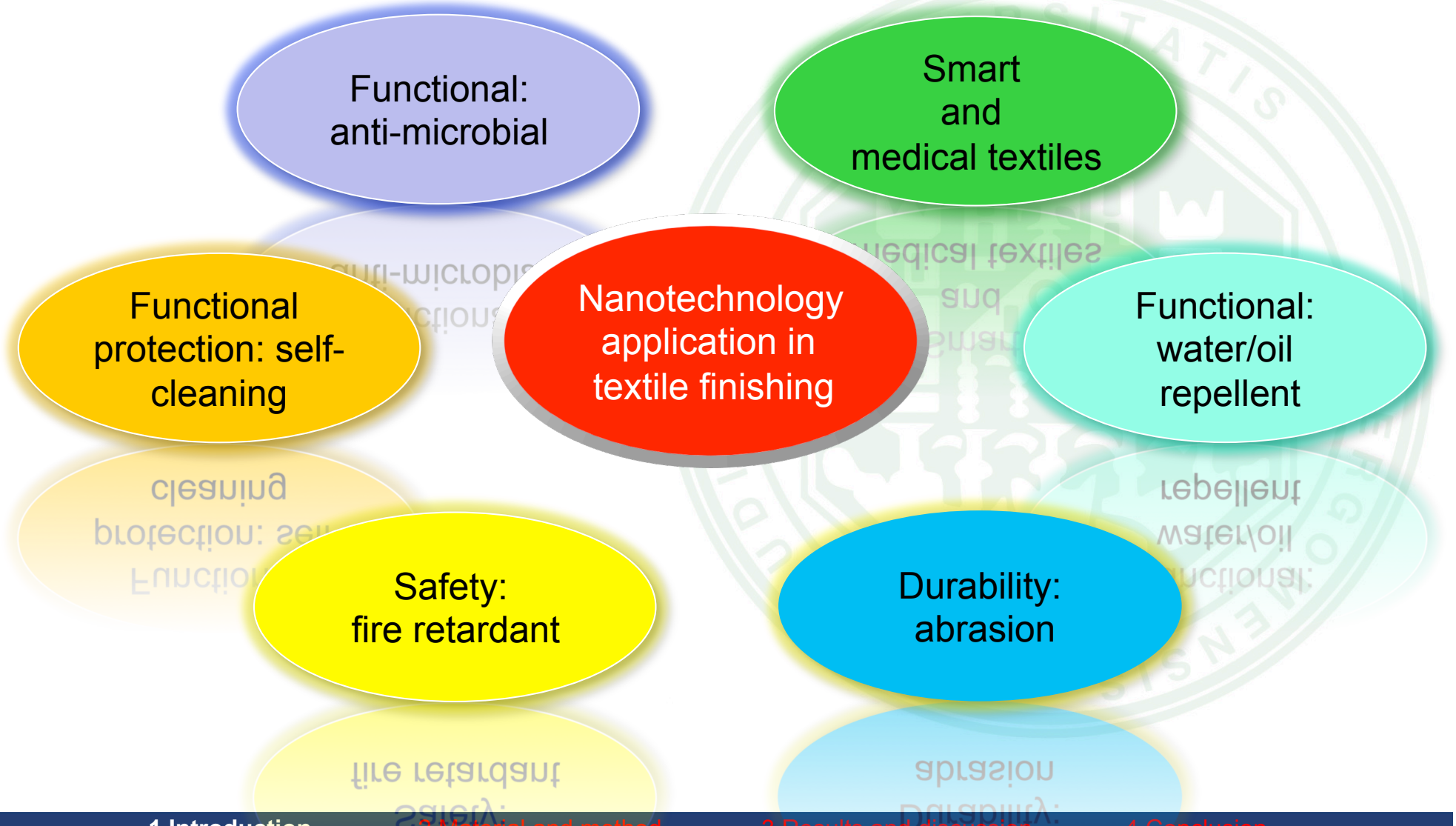
Small batches
Just in time
Customized production



Chemicals
Water use
Energy use

Smart textiles
Protection
Self-cleaning
Multifunctional

INNOVATION IN TEXTILES FINISHING



SOL-GEL CHEMISTRY

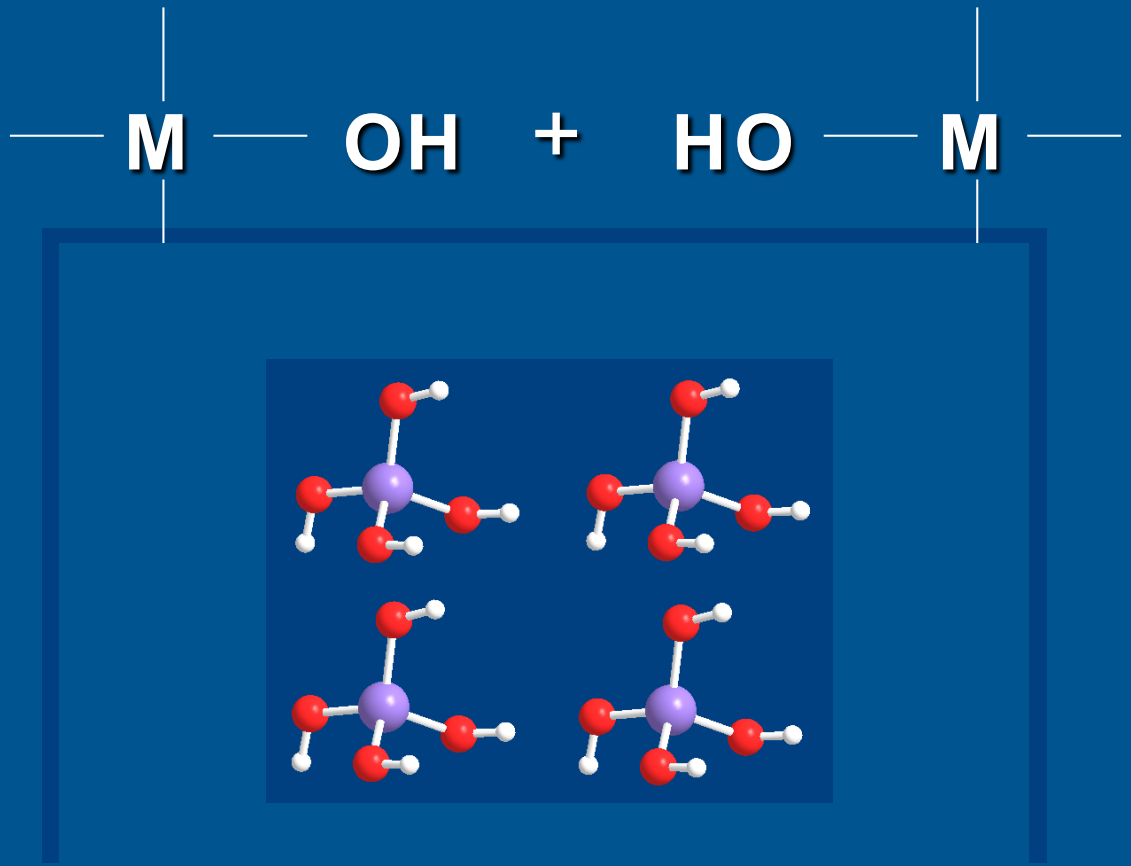
First step: hydroxylation upon the **hydrolysis of alkoxy** groups

Particles in a dispersed state in the solvent realize an independent colloidal suspension **(Sol)**

The usual molecular precursors are metallo-organic compounds such as alkoxides $M(OR)_n$, where M is a metal like Si, Ti, etc. R is an alkyl group (R = CH_3, C_2H_5, etc.). Tetraethylorthosilicate (TEOS), $Si(OC_2H_5)_4$, is commonly used in the sol–gel synthesis of silica

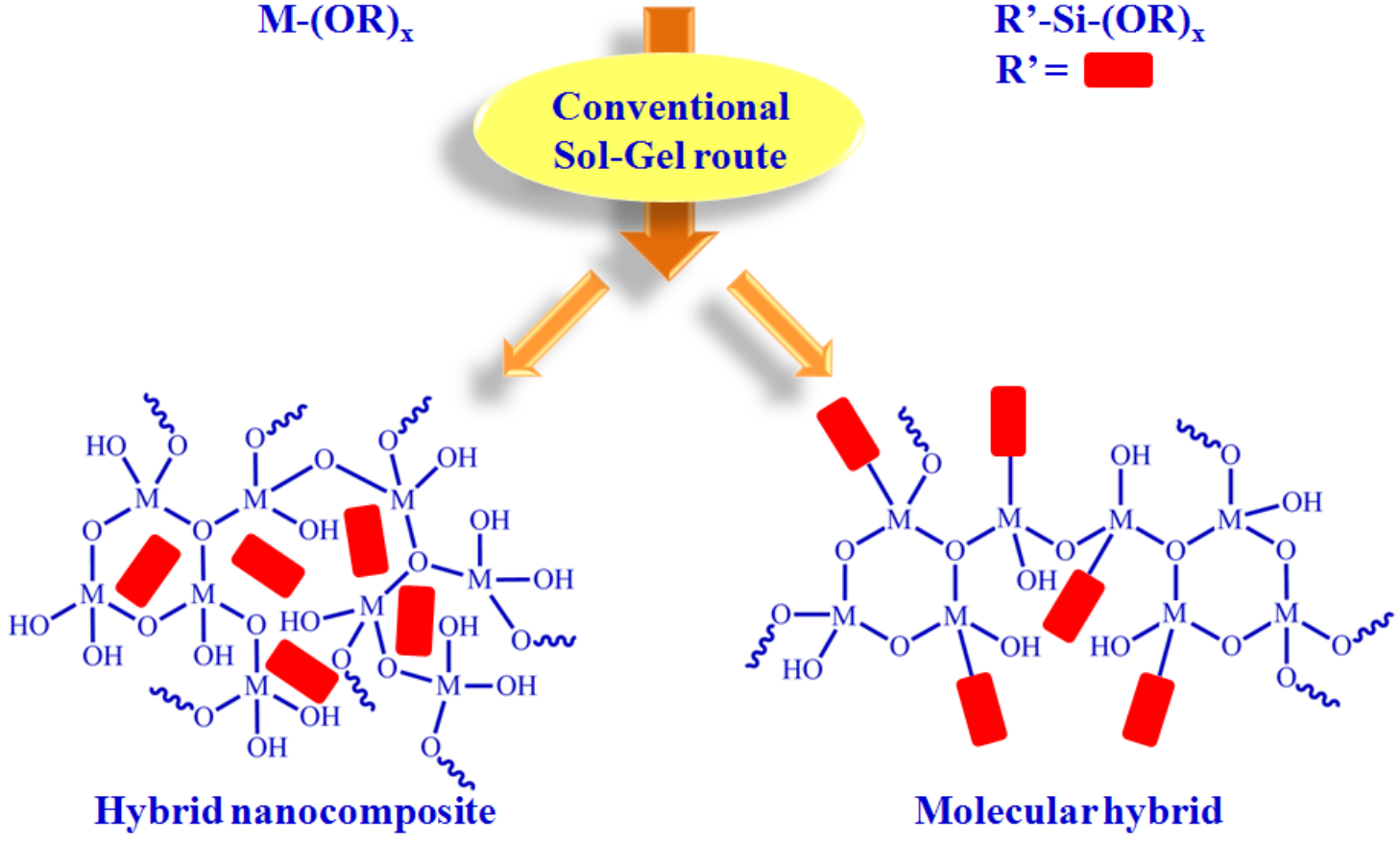
SOL-GEL CHEMISTRY

Second step: polycondensation process leading to the formation of branched oligomers and polymers with a metal oxo based skeleton and reactive residual hydroxo and alkoxy groups



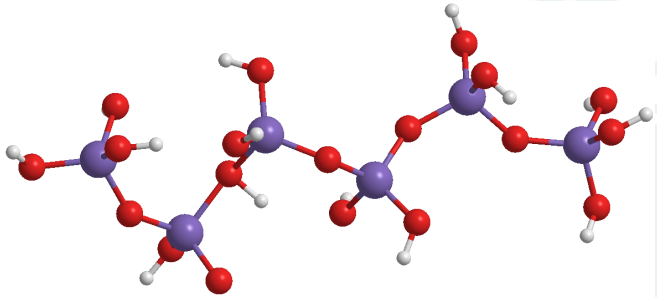
H_2O groups are **eliminated**

HYBRID ORGANIC-INORGANIC MATERIALS



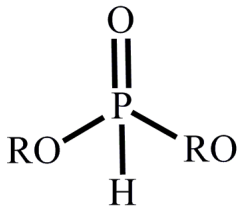
= organic molecule, polymer, bio-polymer

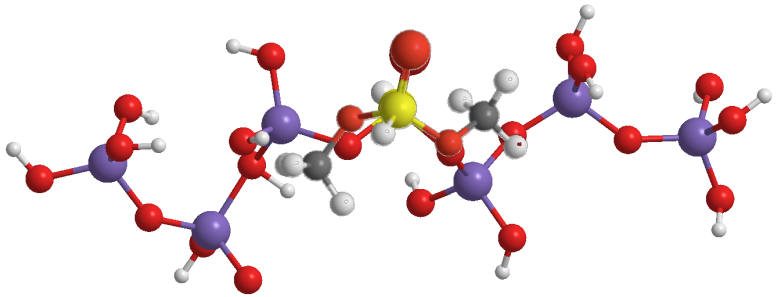
HYBRID ORGANIC-INORGANIC MATERIALS



S

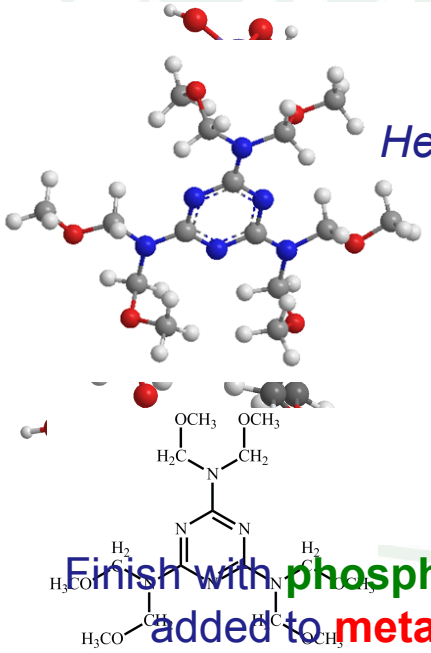
Finish with a metal oxo based skeleton



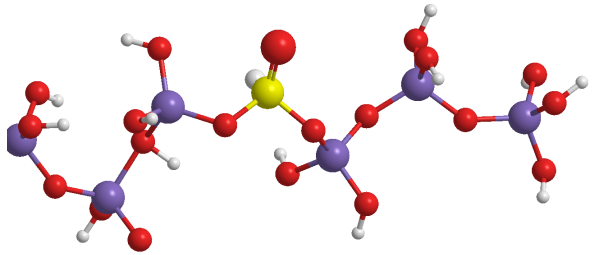


S-P

Finish with **phosphorus (V)** added to **metal oxo based skeleton**



Hexa Methoxymethyl Melamine

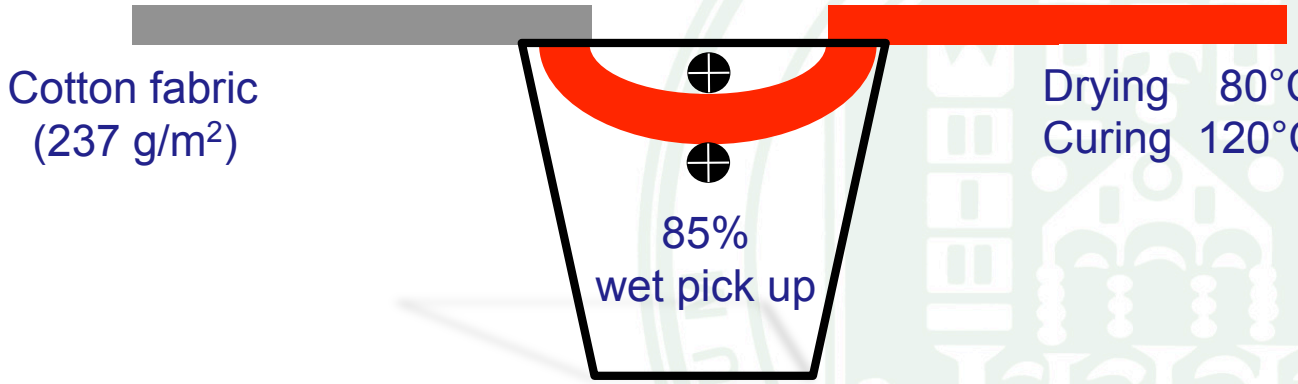


S-P-C

Finish with **phosphorus (V)** and **crosslinker** added to **metal oxo based skeleton**

CHEMICALS AND PROCESSES USED

Untreated textile sample **Finished textile sample**



Finishes:

		Molar Ratio
S:	Sol solution by hydrolized precursor;	1
S-P:	Sol and phosphorus (V) chemical mix;	1 : 1
S-P-C:	Sol, phosphorus (V) and crosslinker chemical mix.	1 : 1 : 0,17

TEXTILE FABRICS CHARACTERIZATION

Morphological and chemical characterization

SEM-EDX, FT-IR

Cellulose degradation mechanism

THERMAL BEHAVIOUR:

Thermogravimetric/Differential Thermal Analysis (TGA/DTG)

Differential Scanning Calorimetry (DSC)

PERFORMANCES TESTED

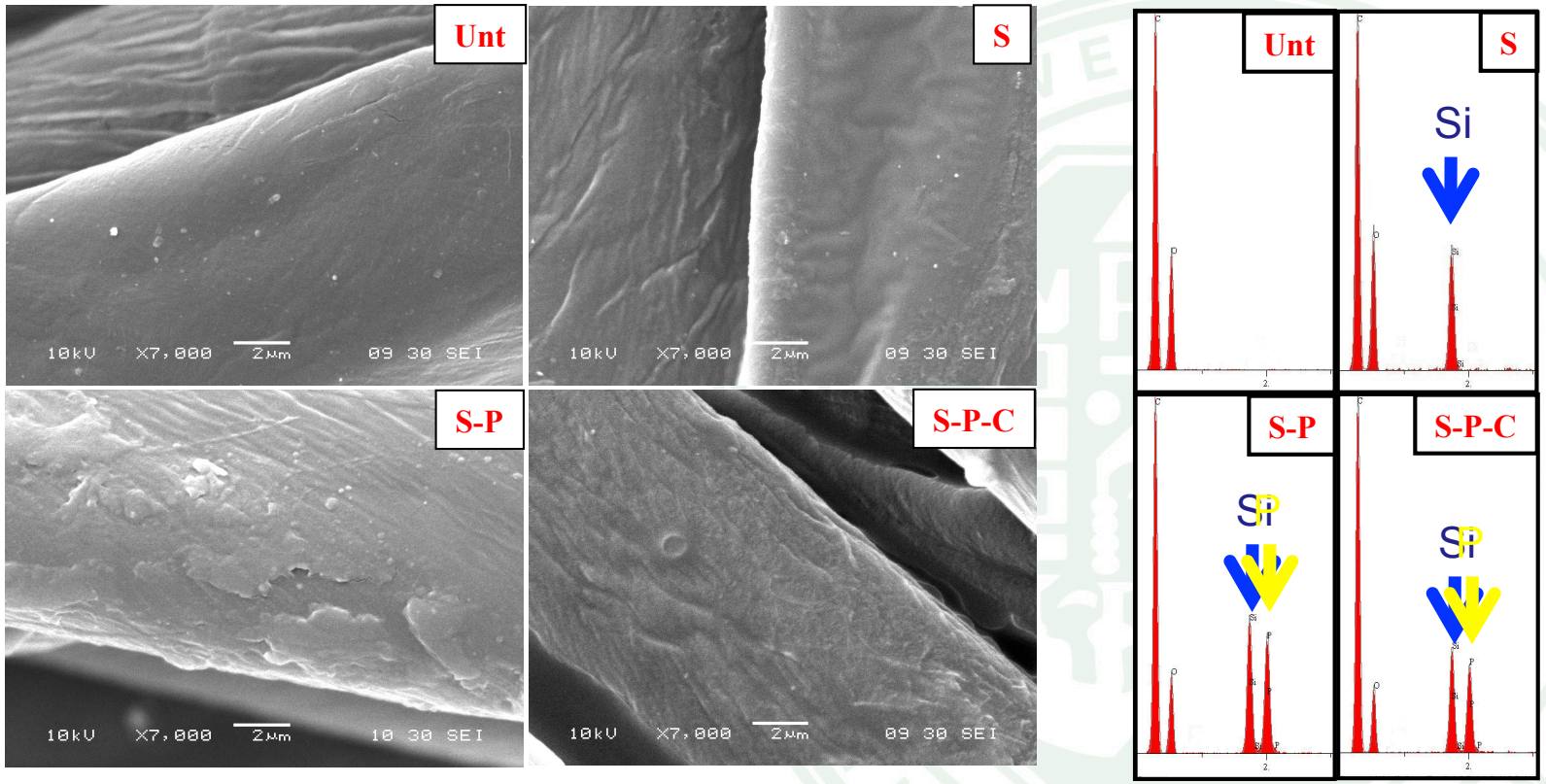
Flame retardant:

Flammability Tester Model 7633E according to ASTM D1230.

Abrasion resistance:

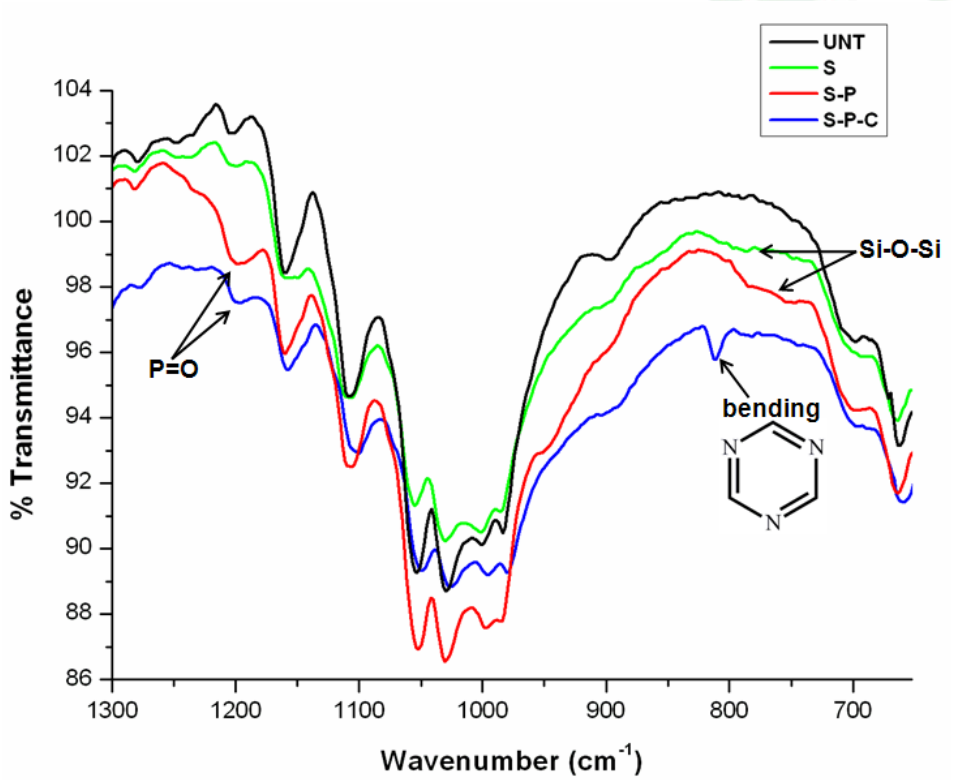
Martindale Abrasion Test Method, according to ISO12947-2000

FILM CHARACTERIZATION: SEM-EDX



Untreated cotton fibres show characteristic parallel grooves. The surface of fabrics treated with pure silica nano-sol (**S**) doesn't show significant modification with respect to the untreated one.
The film becomes evident on the fabric treated with the organic-inorganic nano-sol (**S-P**), where particles are clearly anchored on the fibre surface.
The presence of the cross-linker in the nano-sol formulation (**S-P-C**) makes the hybrid coating more homogeneously distributed around the cotton fibre.

FILM CHARACTERIZATION: FT-IR

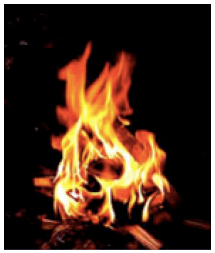


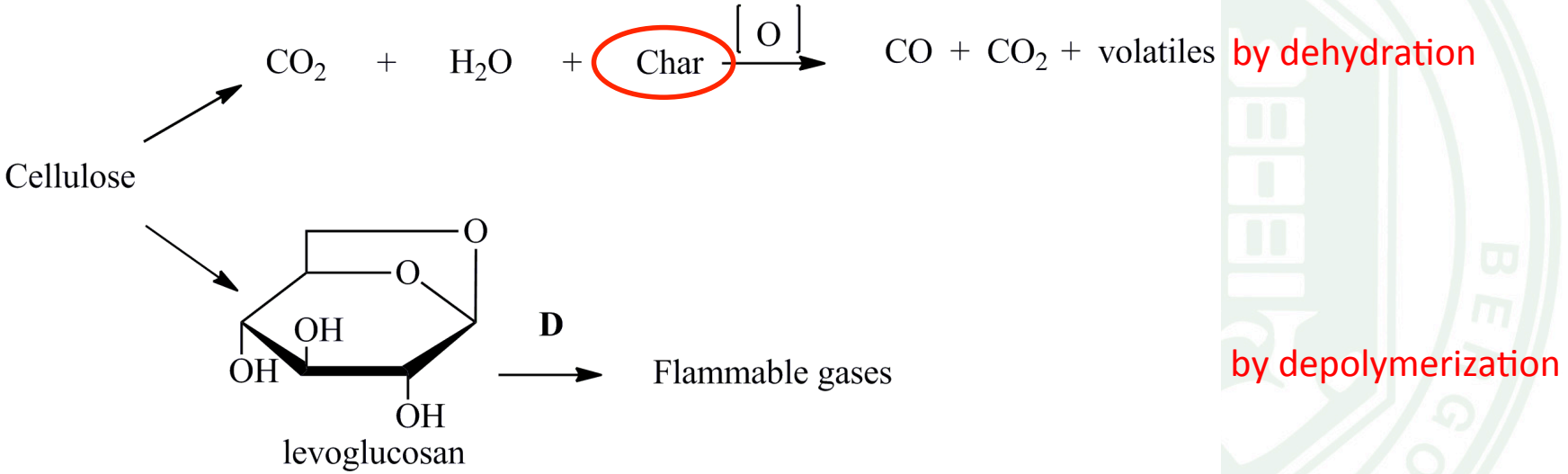
FT IR ATR spectra (between 1300-650 cm^{-1}) of cotton fabrics.

- In **S** and **S-P** spectra Si-O bending band is evident at 800 cm^{-1};
- In **S-P** and **S-P-C** spectra the P=O stretching band (typical of P(V)-compound) appears at 1202 cm^{-1}.

CELLULOSE DEGRADATION MECHANISM

Formation of stable char is one of the desirable mechanisms of flame retardation in polymers, since the char layer acts both as a thermal insulator and as a barrier to oxygen diffusion.



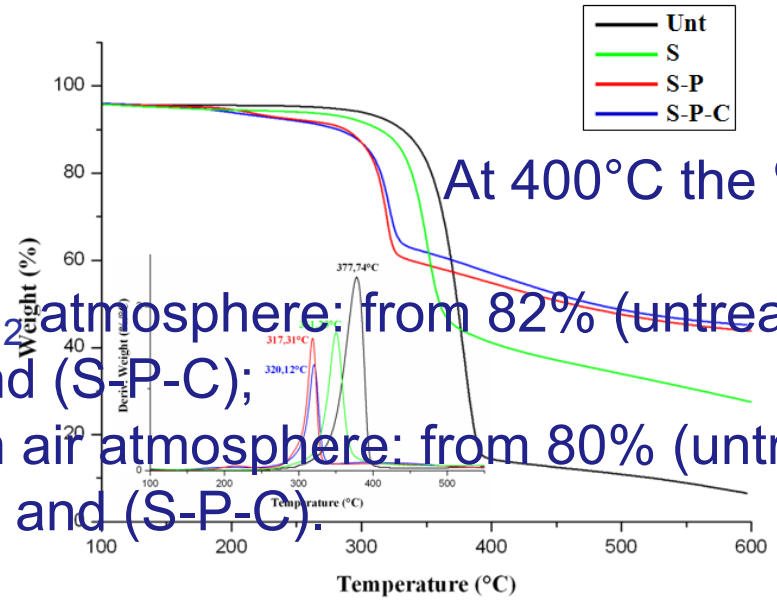


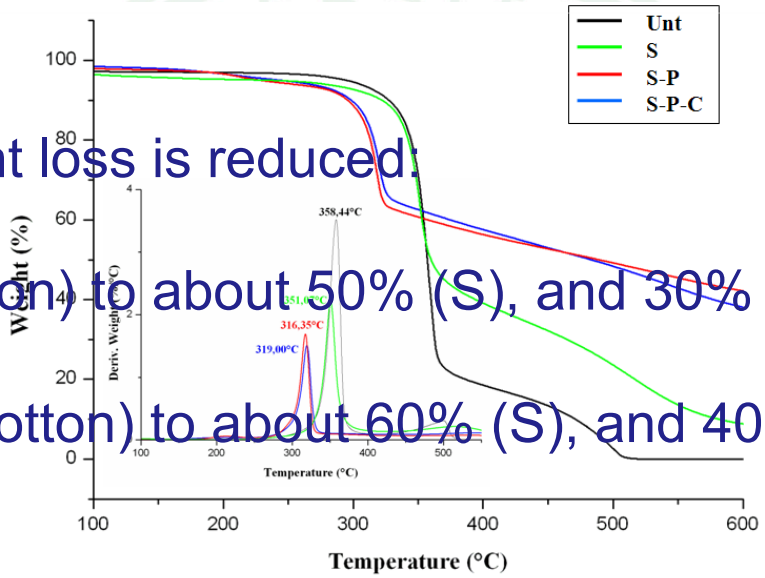
The proposed hybrid finishes combine the following effects:

- **dehydration** favoured by P(V)-compound;
- **stabilization** of the char by silica thin layer (thermal barrier-heat resistance).

THERMAL BEHAVIOUR:

Thermogravimetric/Differential Thermal Analyses (TGA/DTG)



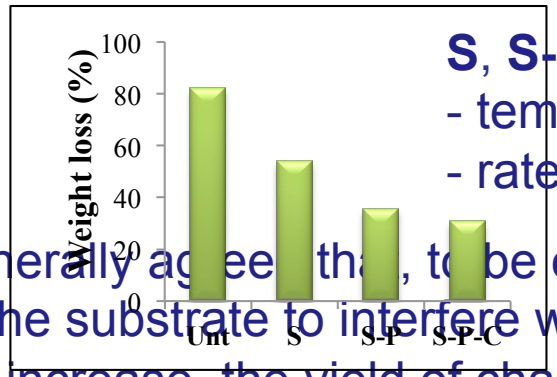


At 400°C the % weight loss is reduced:

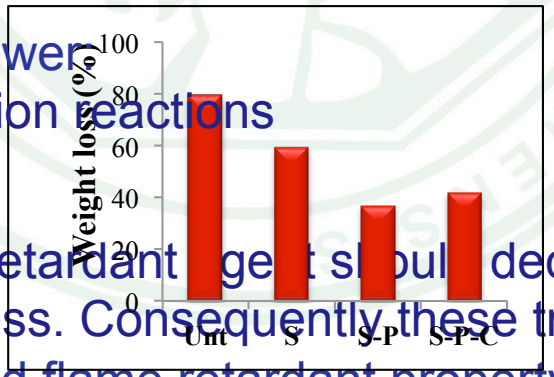
-N_2 atmosphere: from 82% (untreated cotton) to about 50% (S), and 30% (S-P) and (S-P-C);

-in air atmosphere: from 80% (untreated cotton) to about 60% (S), and 40% (S-P) and (S-P-C).

Nitrogen atmosphere



Air atmosphere



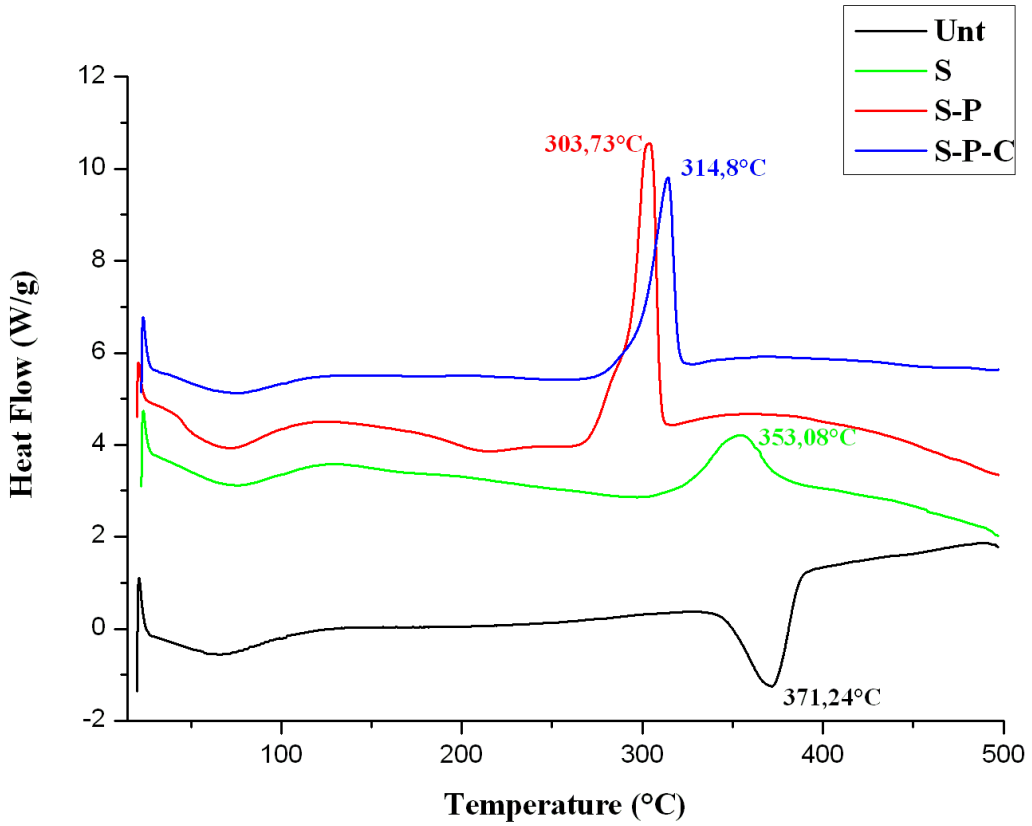
S, **S-P**, **S-P-C** coatings lower
- temperature of gasification reactions
- rate of weight loss.

It is generally agreed that, to be effective, the flame retardant agent should decompose before the substrate to interfere with its burning process. Consequently these treatments increase the yield of char, leading to improved flame retardant property.

THERMAL BEHAVIOUR:

Differential Scanning Calorimetry (DSC)

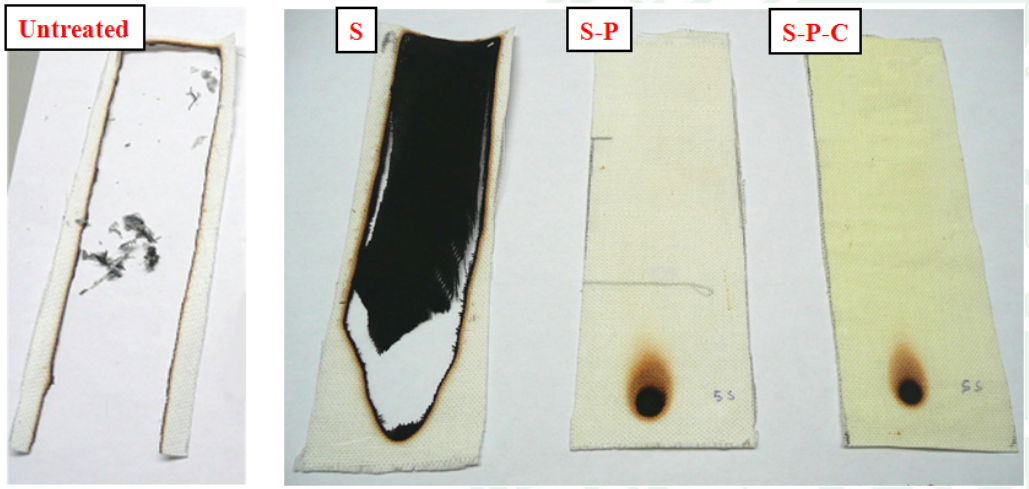
DSC curves of cotton fabrics in nitrogen atmosphere.



The remarkable char formation was confirmed by the DSC analysis.
The exotherm peaks are due to chemisorptions of oxygen on the nascent char.
The endothermic peak due to cellulose decomposition at 370°C is shifted to lower temperature for the sample treated with **S** nano-sol, whereas an exothermic peak appears at 353°C, getting sharper for the fabrics treated with **S-P** and **S-P-C** hybrid formulations.
This reaction is known to be highly exothermic and results in the formation of stable surface oxides which stabilize the char toward combustion.

FLAMMABILITY TESTS

Flammability Tester Model 7633E according to ASTM D1230
(after a 5 s flame exposition)



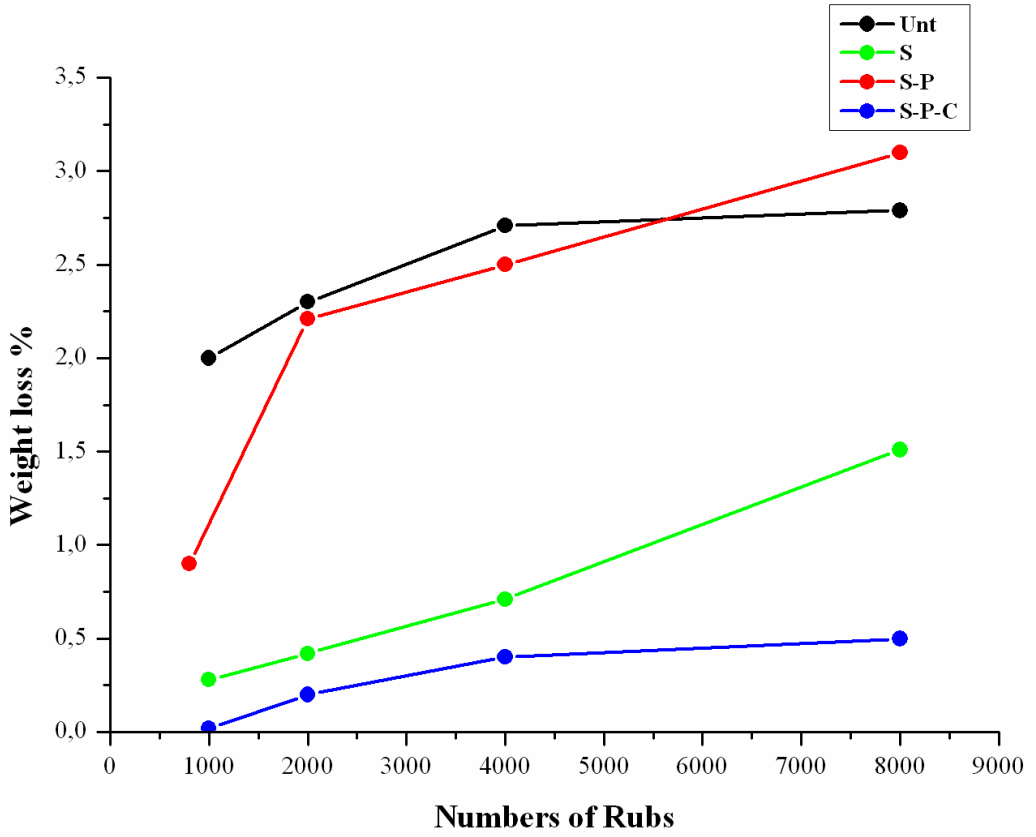
Untreated cotton fabric burns with a rapid flame

The treatment with pure silica nano-sol (**S**) slows down the cellulose combustion.

S-P and **S-P-C** treatments have brought nonflammable property to cotton fabrics.

ABRASION RESISTANCE OF FABRICS

Martindale Abrasion Test Method, according to ISO12947-2000



Martindale test results for untreated and treated cotton fabrics: weight loss % versus numbers of rubs.

CONCLUSION

- ✓ The sol-gel process allows to realize multifunctional textile surface
- ✓ “Hybrid Organic-Inorganic” finishes are synthesized in water or hydroalcoholic solution at low temperature
- ✓ The amount of chemicals applied is lower than in traditional treatments
- ✓ The polymerization occurs at temperature lower than actual finishing
- ✓ The flame retardant treatment does not require any additional process/ chemical for curing
- ✓ Applications are made using traditional equipments

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