STUDY OF FLAME RETARDANCY PROPERTIES OF NANOPARTICLE-BASED TEXTILE FABRICS

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OUTLINE

- TOP-DOWN approach
  - Simply immersion (S_I)
  - Plasma surface modification (PT)
  - Results
- BOTTOM-UP approach
  - Sol-gel process
- Conclusions

TOP-DOWN Approach

NANOPARTICLES & TEXTILE FABRICS USED

Textile fabrics:

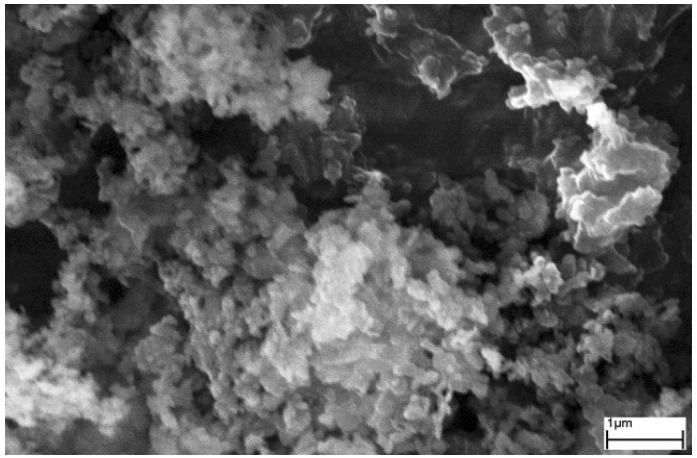
- 100% polyester (PET)
- 100% cotton (COT)
- 65% polyester + 35% cotton (PET-COT)

Nanoparticles:

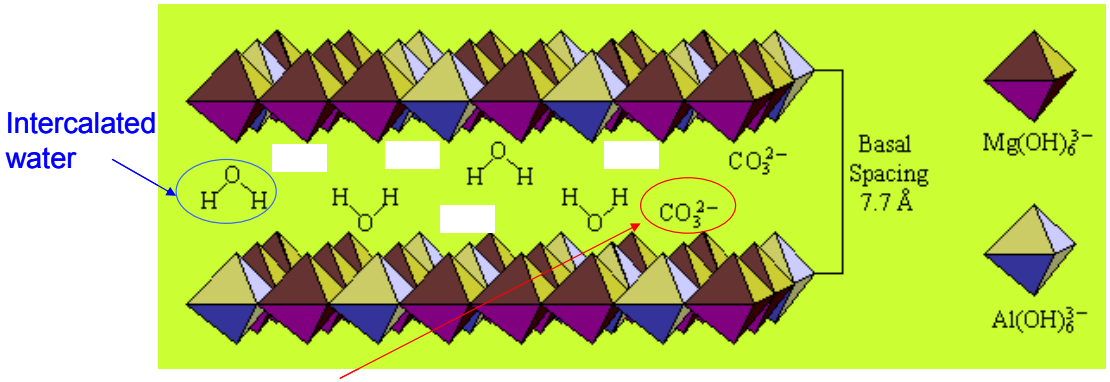
- Hydrotalcite (Pural MG63HT – Sasol)
- SiO_2 (Sidistar T120 – Elkem AS)

CHARACTERIZATION

HYDROTALCITE

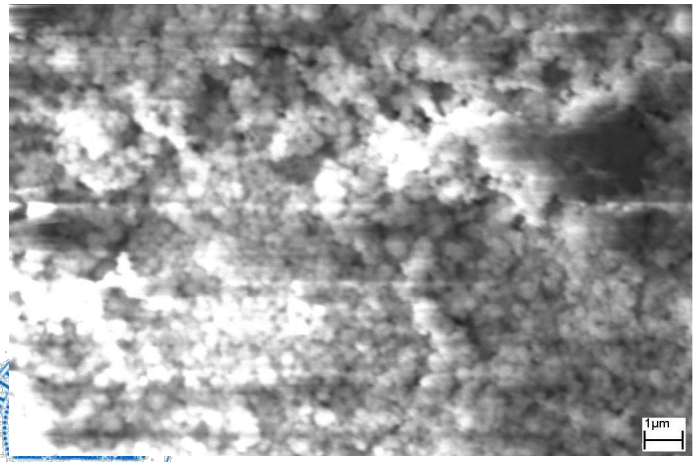


Hydroxides Layers: **positive** charge

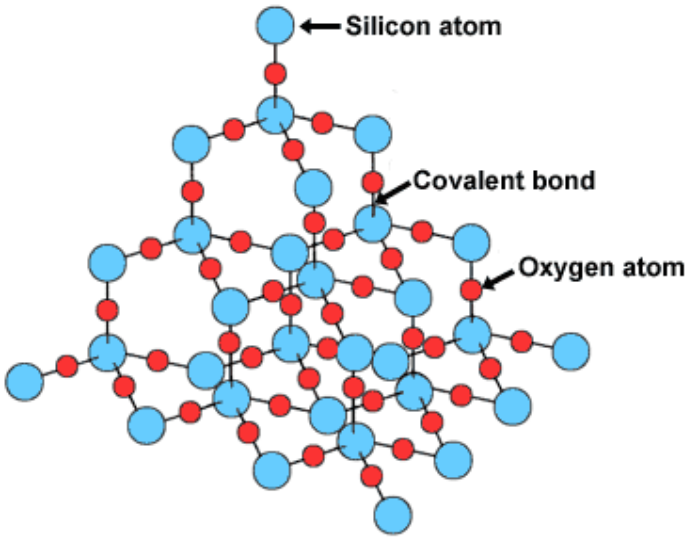


Interstitial **anions** to compensate positive layers

SiO_2



Nano-size spherical amorphous silicon dioxide

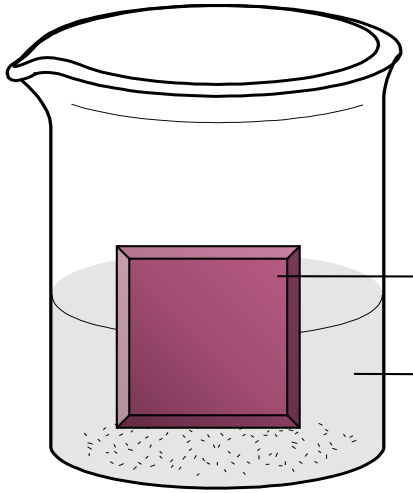


EXPERIMENTAL SECTION

PREPARATION OF NP-BASED TEXTILE FABRICS

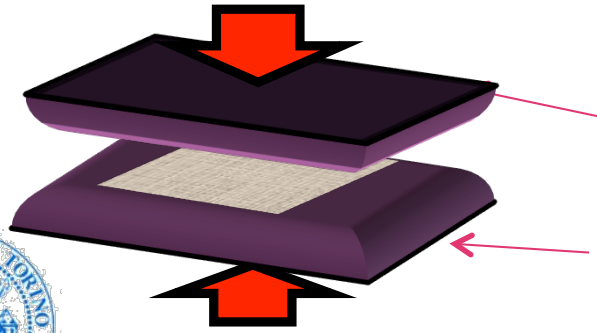
Simply immersion

- 1° step: immersion of textile into NP suspension



Immersion time= 30 or 60 min

- NP fixation by thermal treatment



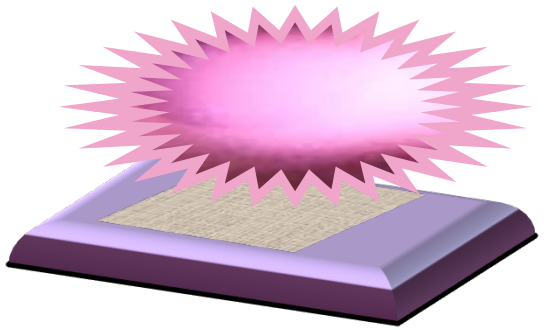
Hot disks

@ T= 200°C, P= 2.5Ton for 10min

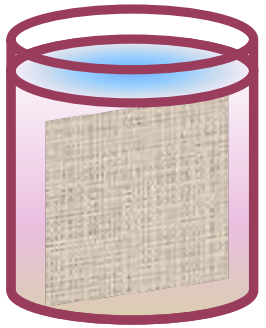
EXPERIMENTAL SECTION

PREPARATION OF NP-BASED TEXTILE FABRICS

- Plasma etching of the surface (O_2)

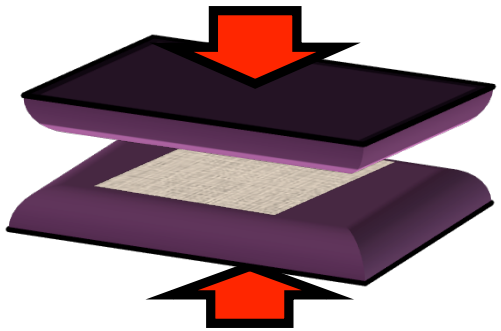


- Immersion for 60min in a NP suspension



- NP fixation by thermal treatment

@ T=200°C, P=2.5Ton for 10min

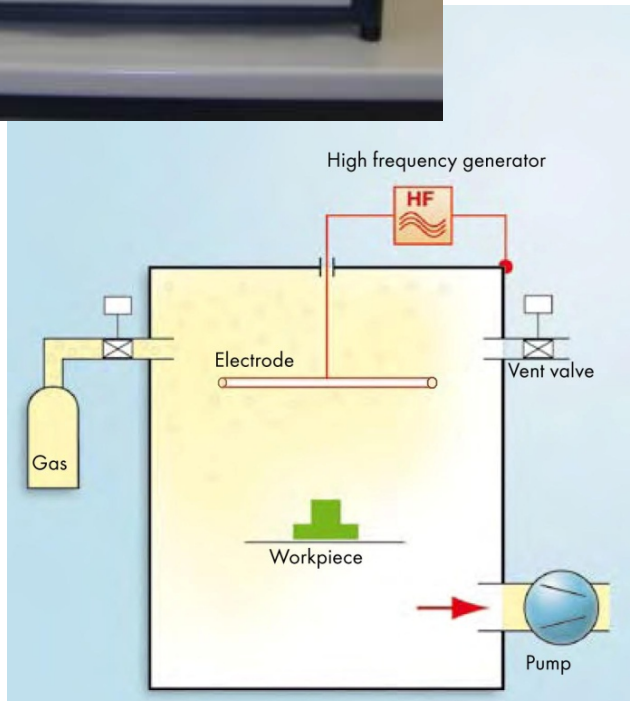


Plasma surface modification

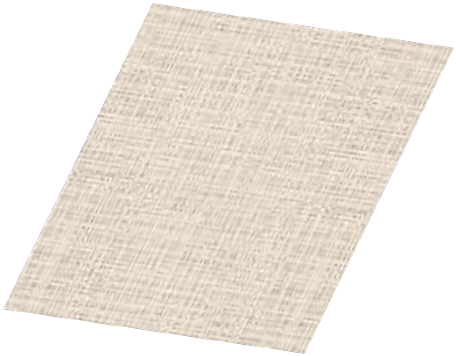
Plasma surface modifications:

ETCHING APPARATUS AND CONDITIONS

Cold plasma RF 40 kHz



Sample for etching process



Textile fabric 20x10 cm

Etching conditions:
Gas: O_2
Pressure: $5x10^{-1}$ mbar
Power: 200 W
Time: 5 min

CONE CALORIMETRY (ISO 5660)

THE PRINCIPLE OF OXYGEN CONSUMPTION CALORIMETRY

HRR, *Heat Release Rate*

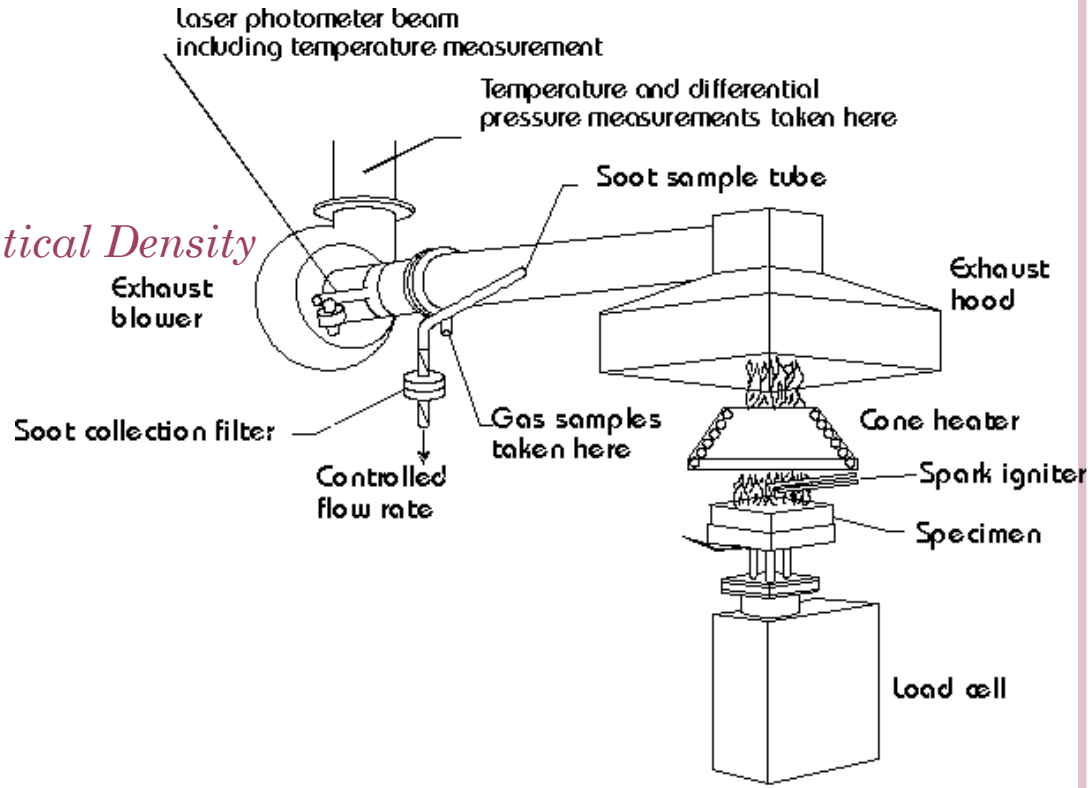
THR, *Total Heat Release*

TTI, *Time To Ignition*

TSR, *Total Smoke Release and OD, Optical Density*

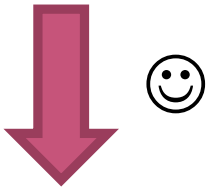
Mass or residue

CO_2 and CO amount



Fire Performance Index (FPI)

$$FPI = \frac{pkHRR}{TTI}$$



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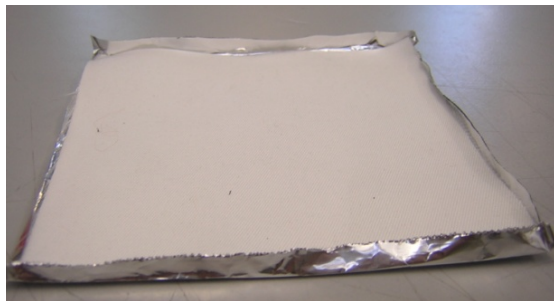
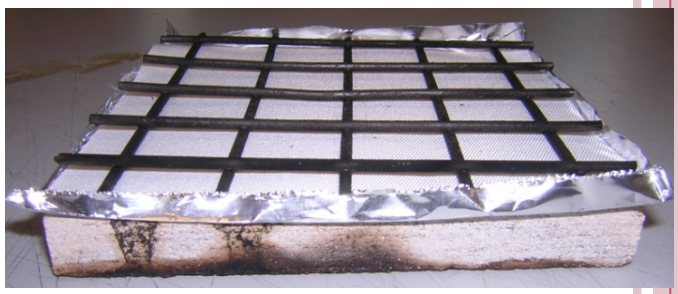
Specimen size: 100x100x0.5 mm
Heat Flux: 35 kW/m²





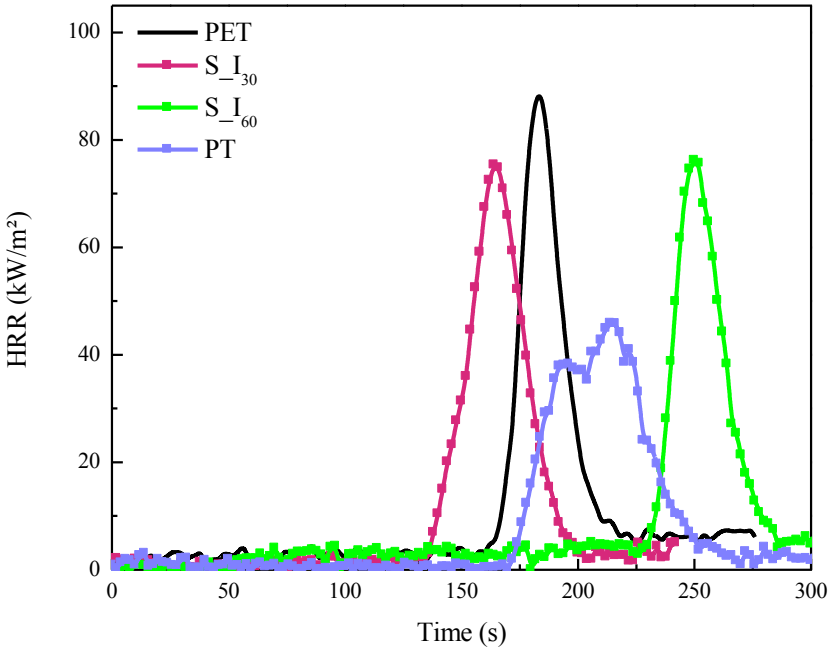
J.Tata *et al.*, submitted to *Fire and Materials*.

RESULTS

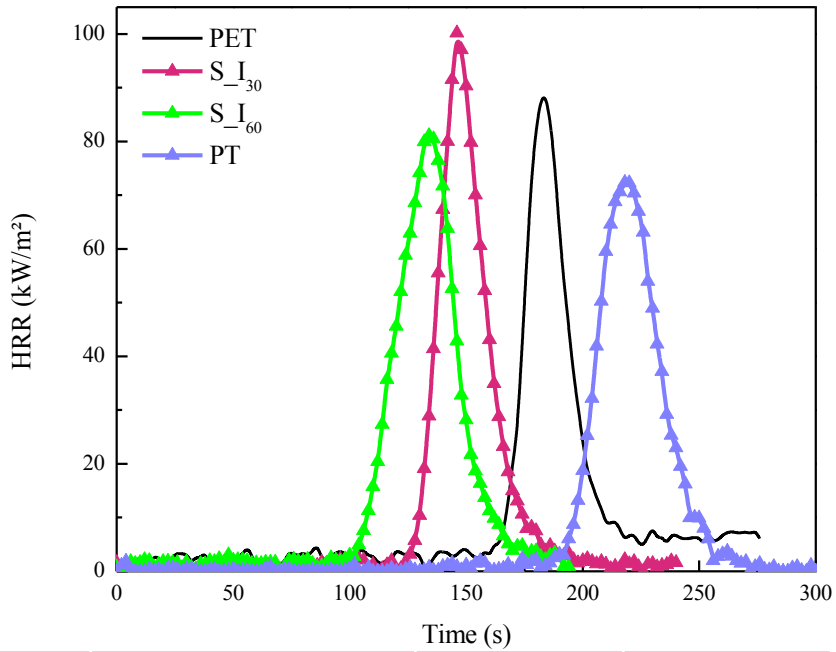
CONE CALORIMETRY

PET textiles

Hydrotalcite loaded textiles



SiO_2 loaded textiles



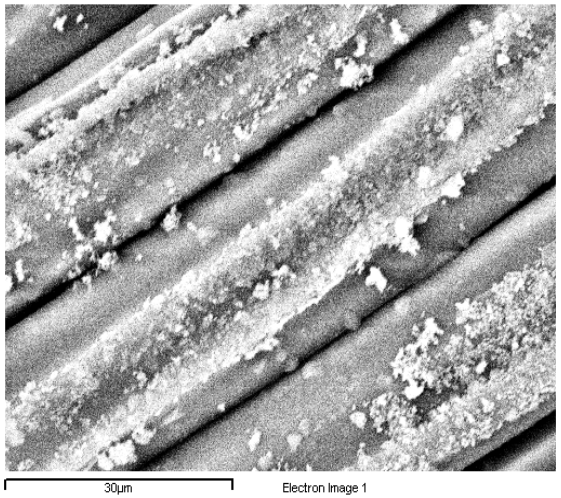
		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	PET	166	-	95	-	0,57
HT	S_I_{30}	134	-32	75	-21	0,56
HT	S_I_{60}	226	+60	76	-20	0,34
HT	PT	170	+4	45	-53	0,26
SiO_2	S_I_{30}	122	-44	100	+5	0,82
SiO_2	S_I_{60}	105	-61	81	-15	0,77
SiO_2	PT	192	+26	72	-24	0,38

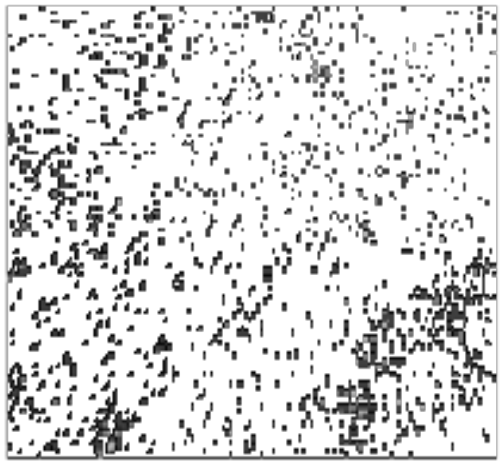
RESULTS

SEM & EDS

PET textiles

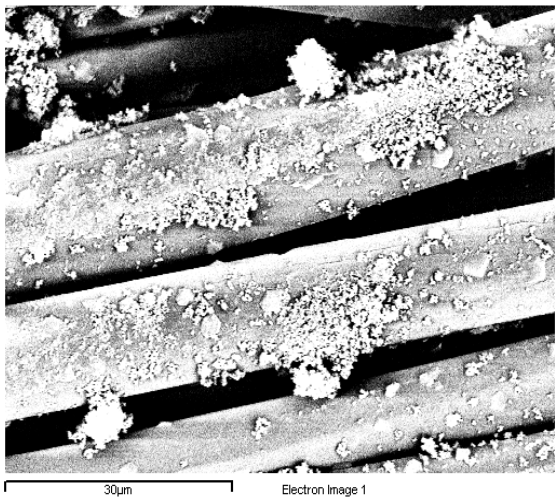
S_I_{60} in SiO_2

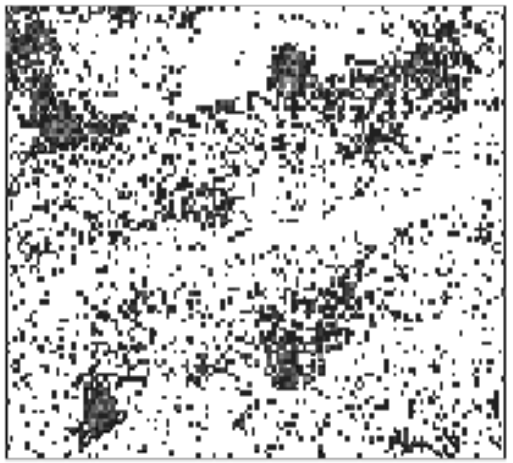




Si

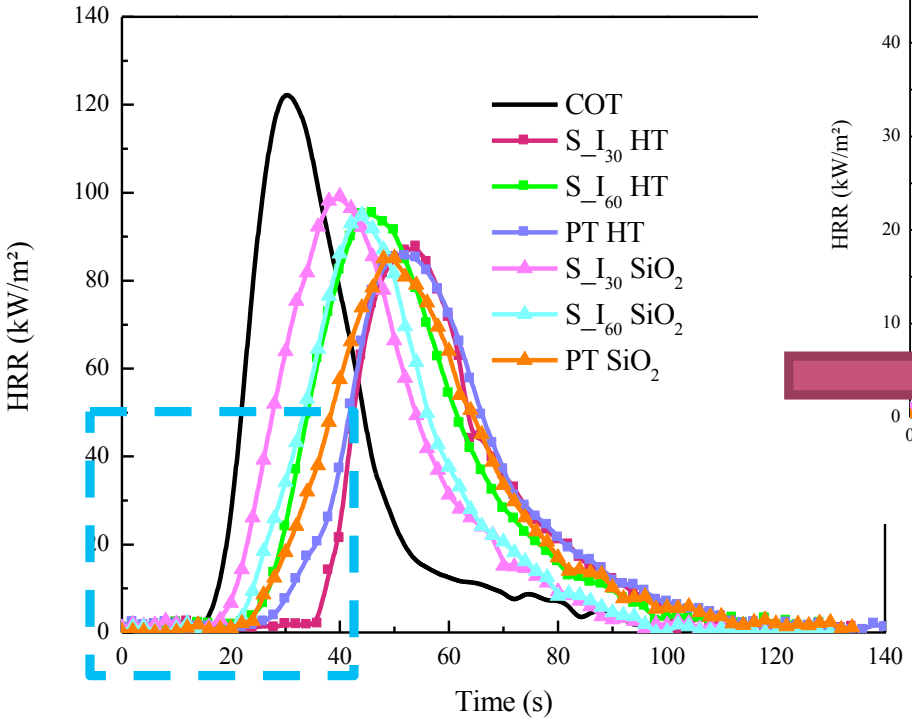
PT in SiO_2

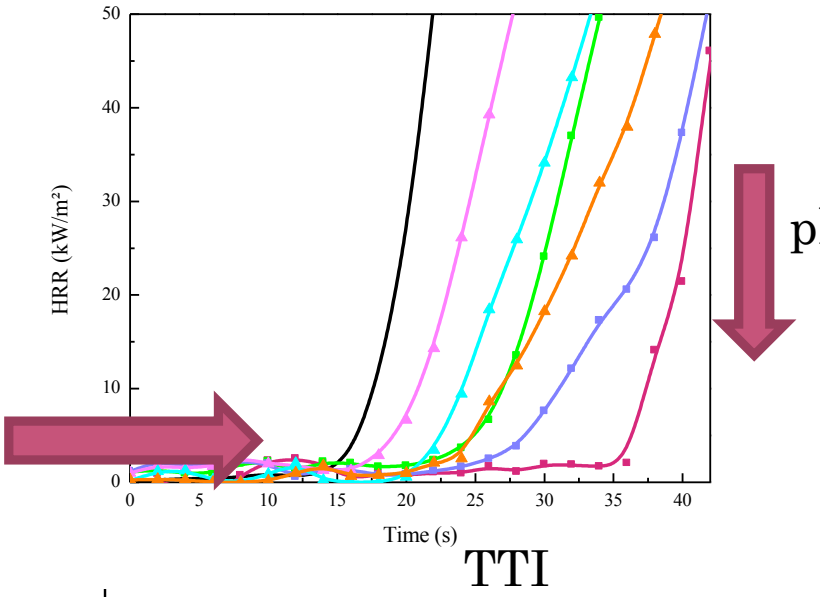




RESULTS

CONE CALORIMETRY



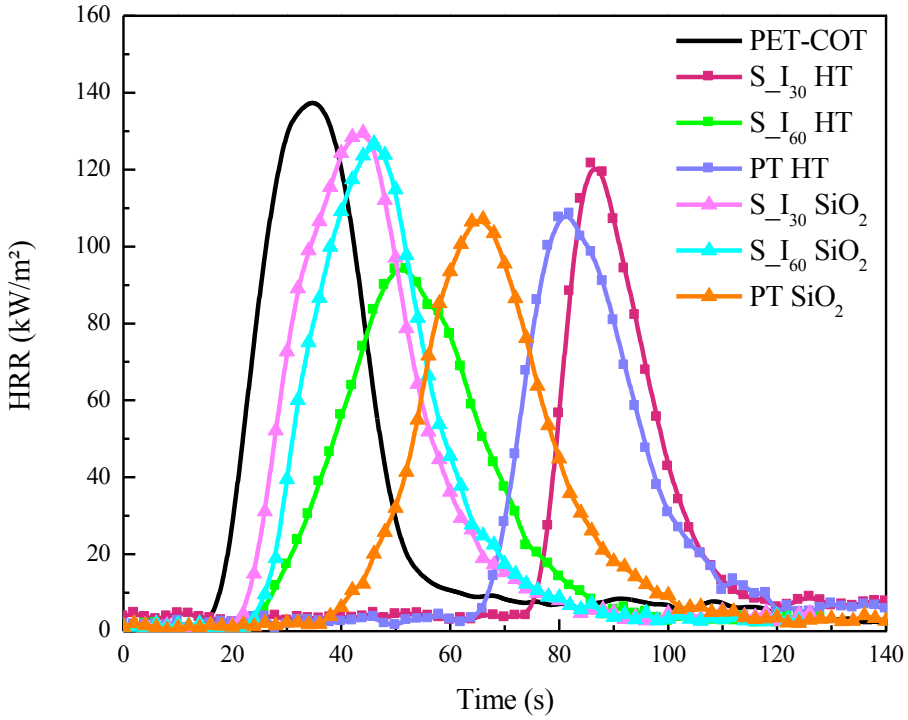


COT textiles

		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	COT	14	-	124	-	8,86
HT	S_I_{30}	36	+22	87	-30	2,42
HT	S_I_{60}	22	+8	95	-23	4,32
HT	PT	22	+8	86	-31	3,91
SiO_2	S_I_{30}	16	+2	99	-20	6,19
SiO_2	S_I_{60}	18	+4	95	-23	5,28
SiO_2	PT	20	+6	86	-31	4,30

RESULTS

CONE CALORIMETRY



TTI

pkHRR

		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	PET-COT	14	-	138	-	9,86
HT	S_I_{30}	74	+60	121	-12	1,64
HT	S_I_{60}	20	+6	94	-32	4,70
HT	PT	64	+50	108	-22	1,69
SiO_2	S_I_{30}	20	+6	130	-6	6,50
SiO_2	S_I_{60}	20	+6	127	-8	6,35
SiO_2	PT	36	+22	107	-22	2,97

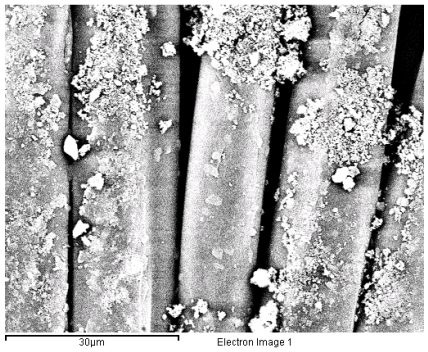
PET-COT textiles

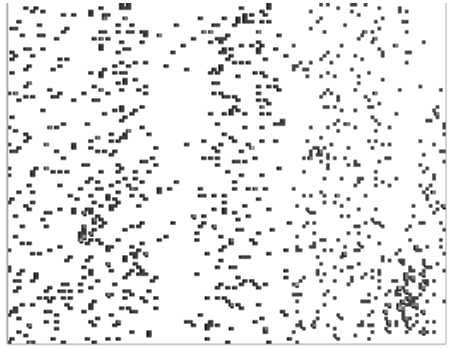
Synergism between HT and SiO_2

SEM & EDS

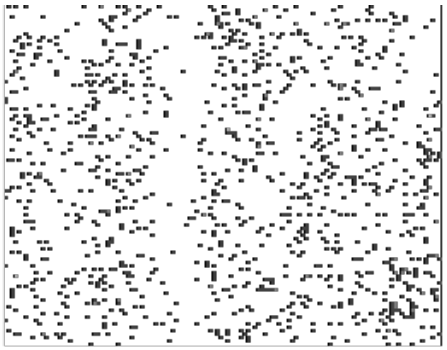
PET textiles

Immersed for 30min

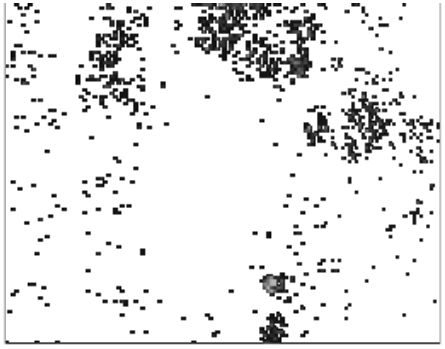




Mg

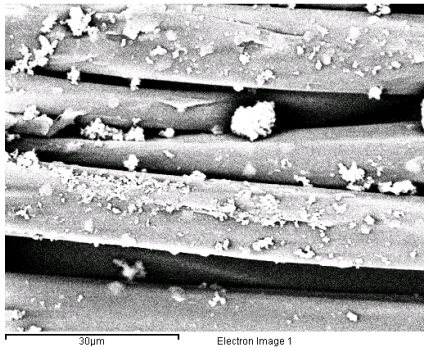


Al

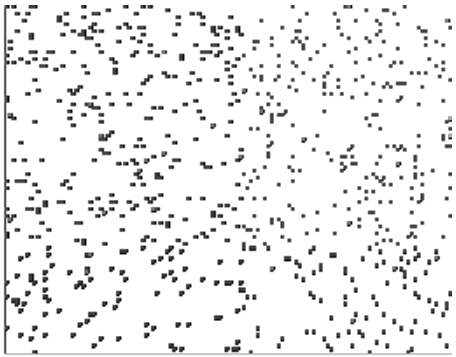


Si

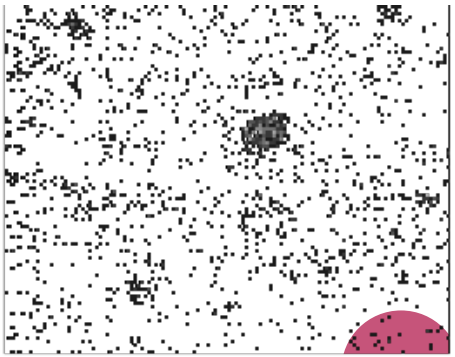
Immersed for 60min



Mg



Al



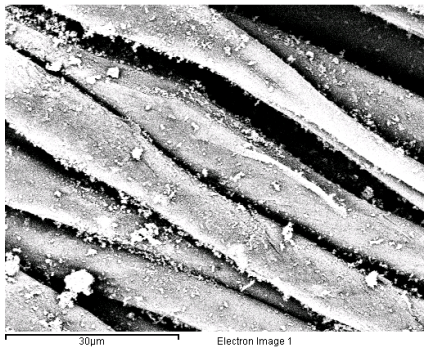
Si

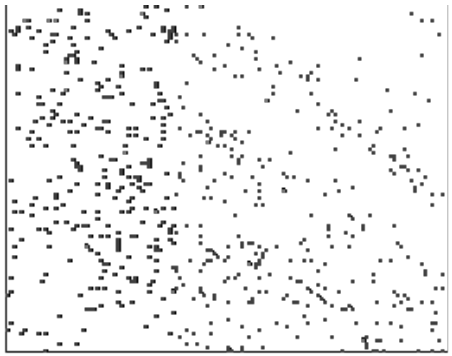
RESULTS

COT textiles

SEM & EDS

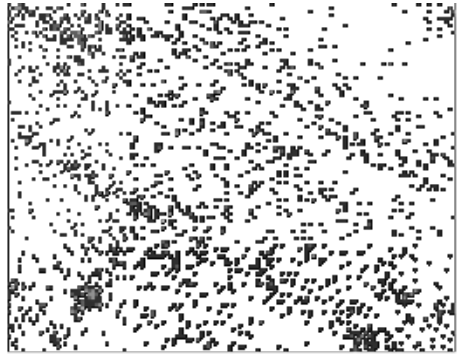
Immersed for 30min





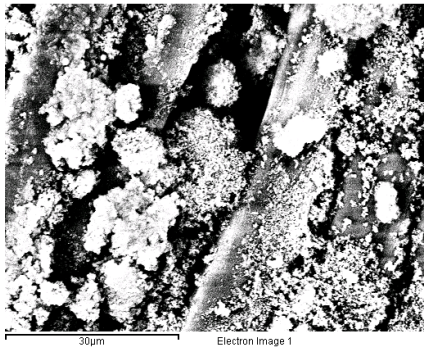
Mg

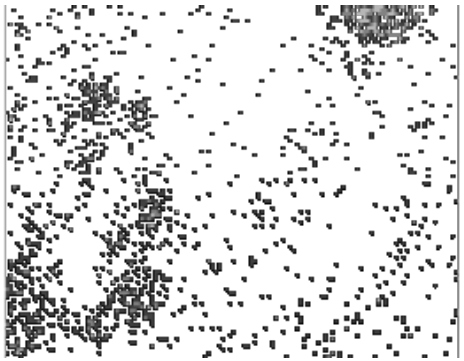
Al



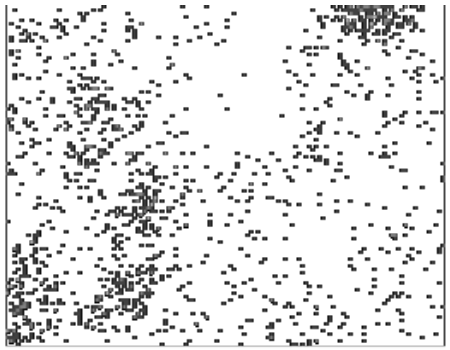
Si

Immersed for 60min





Mg

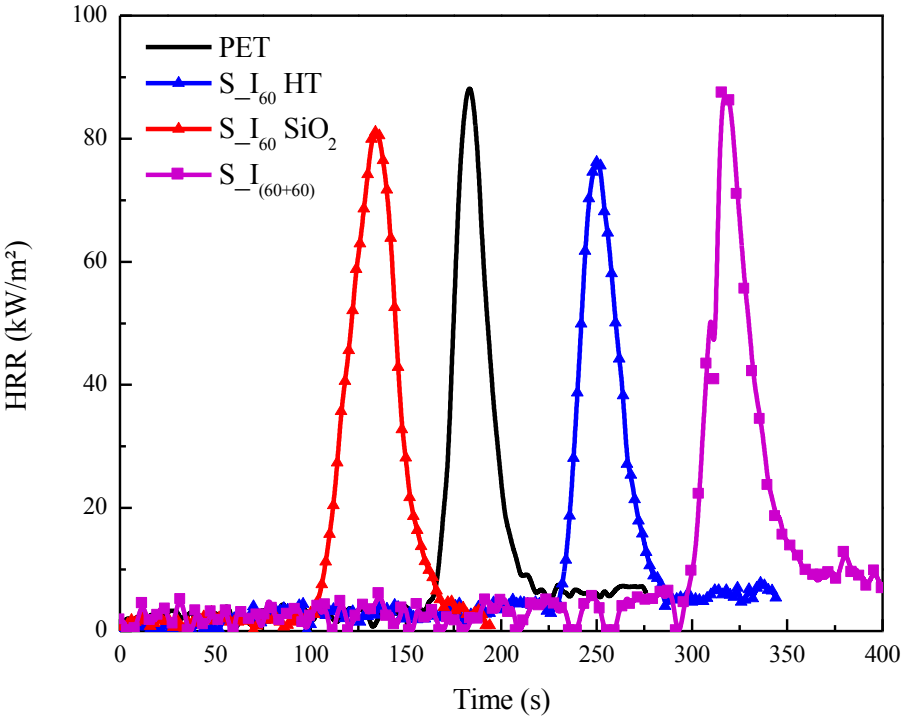


Al

Si

Synergism between HT and SiO_2

CONE CALORIMETRY



TTI

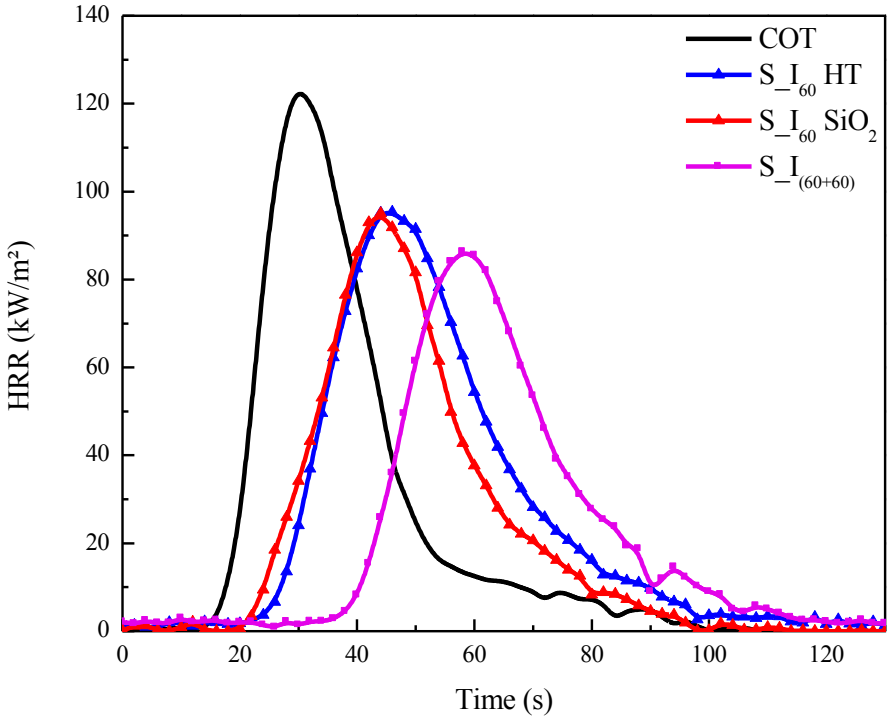
pkHRR

PET textiles

		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	PET	166	-	95	-	0,57
HT	S_I_{60}	226	+60	76	-20	0,34
SiO_2	S_I_{60}	105	-61	81	-15	0,77
	$S\_I_{(60+60)}$	294	+128	87	-8	0,30

Synergism between HT and SiO_2

CONE CALORIMETRY



TTI

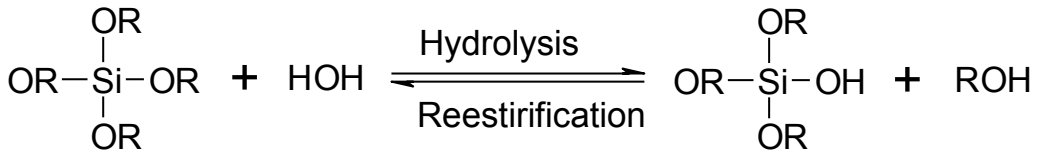
pkHRR

		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	COT	14	-	124	-	8,86
HT	S_I_{60}	22	+8	95	-23	4,32
SiO_2	S_I_{60}	18	+4	95	-23	5,28
	$S\_I_{(60+60)}$	34	+20	86	-31	2,53

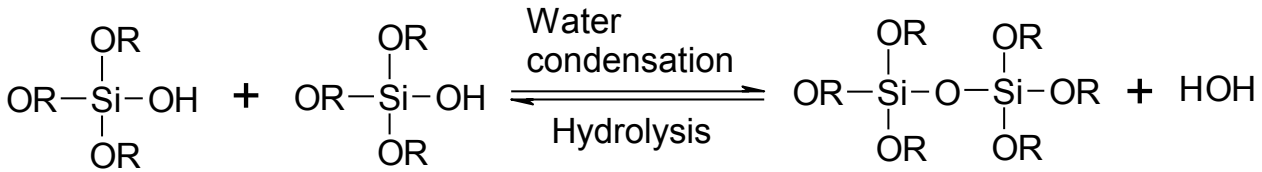
COT textiles

BOTTOM-UP Approach

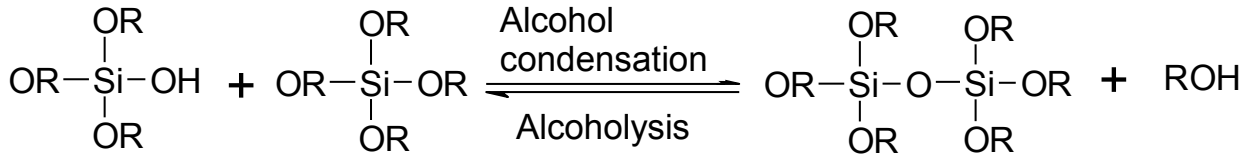
PREPARATION OF NP-BASED TEXTILE FABRICS



(1)



(2a)



(2b)

where R= -CH_2CH_3 Tetraethoxysilane (TEOS)

1:1

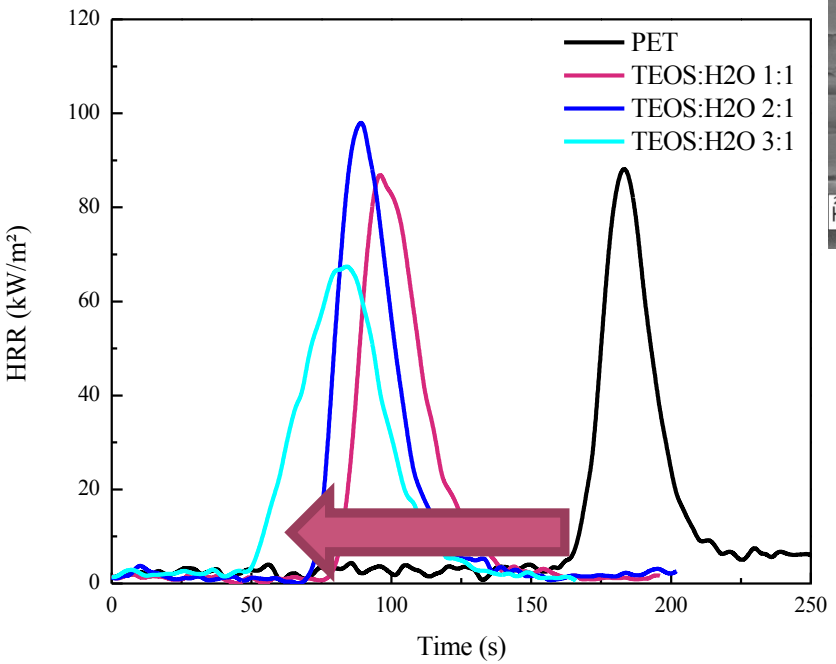
TEOS:H_2O 2:1

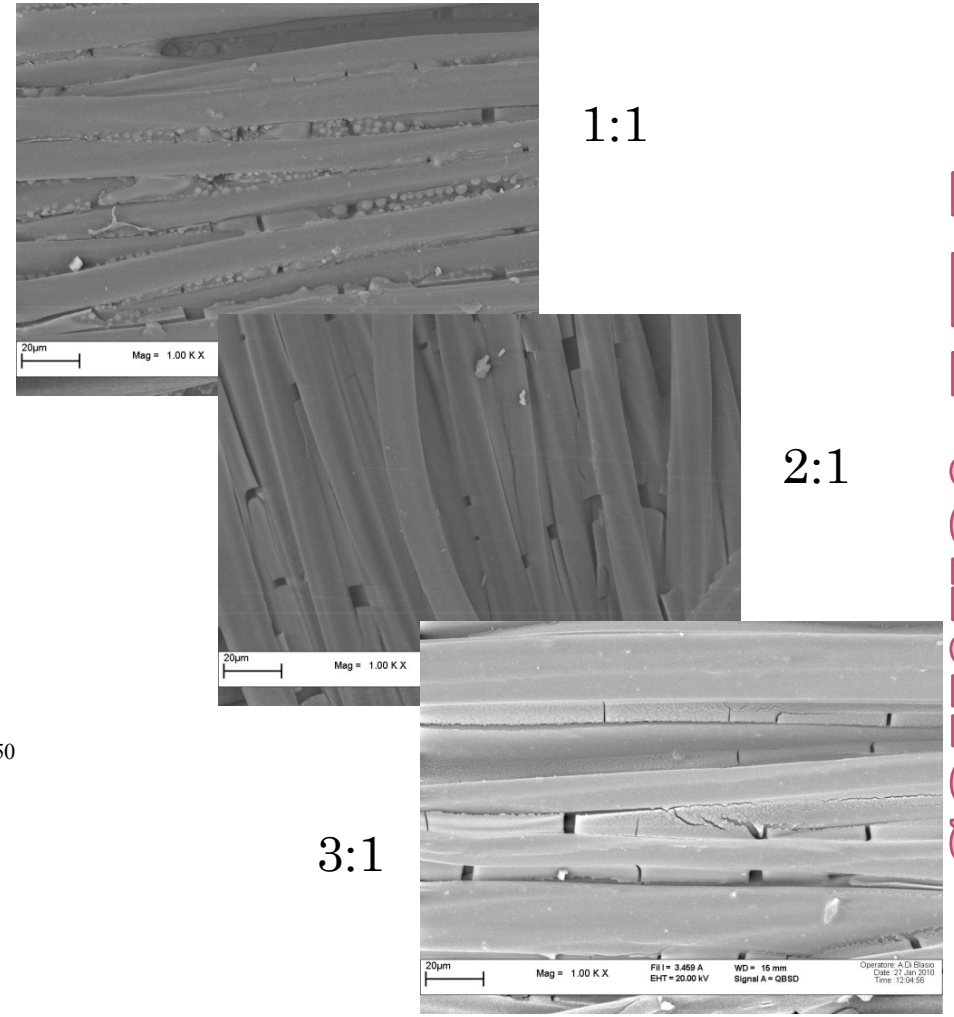
3:1

Sol-gel Process

RESULTS

CONE CALORIMETRY



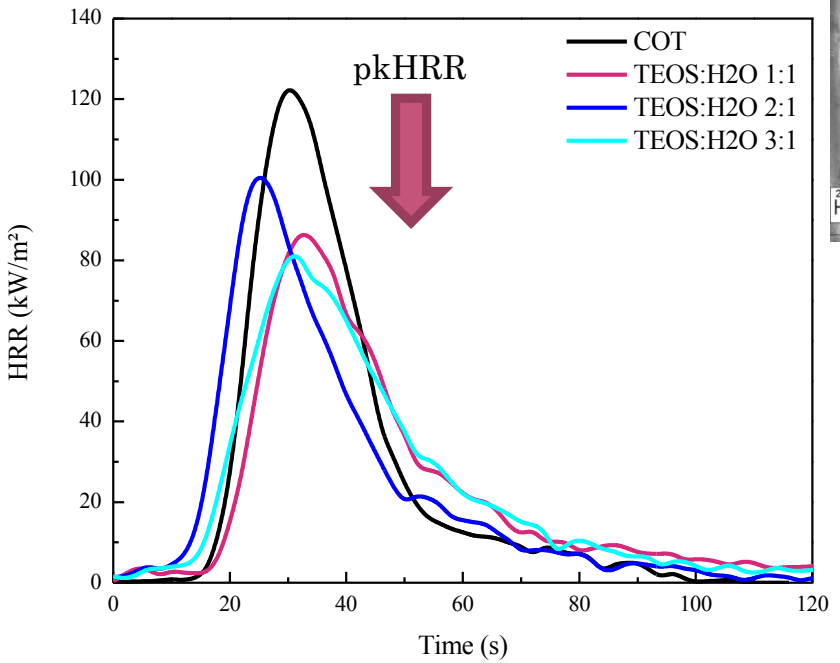


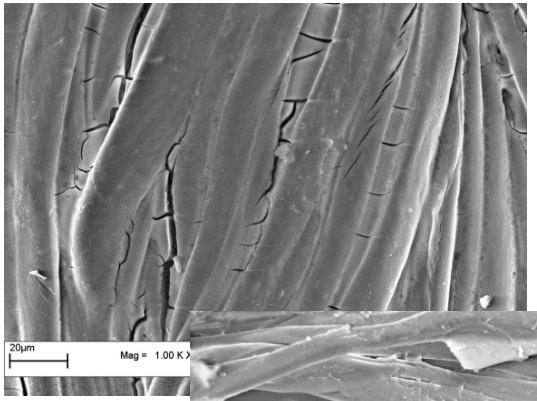
PET textiles

		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	PET	166	-	95	-	0,57
TEOS:H_2O	1:1	74	-92	88	-7	1,19
	2:1	68	-98	99	+4	1,46
	3:1	46	-120	68	-28	1,48

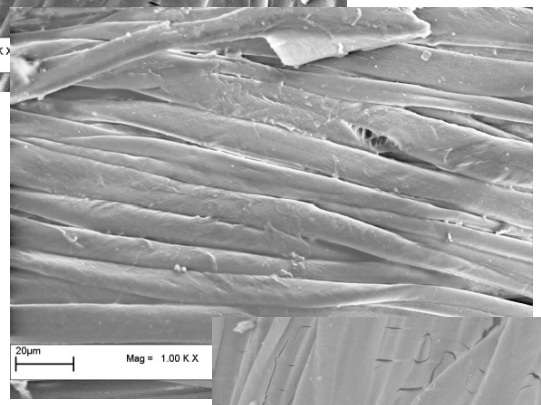
RESULTS

CONE CALORIMETRY





1:1



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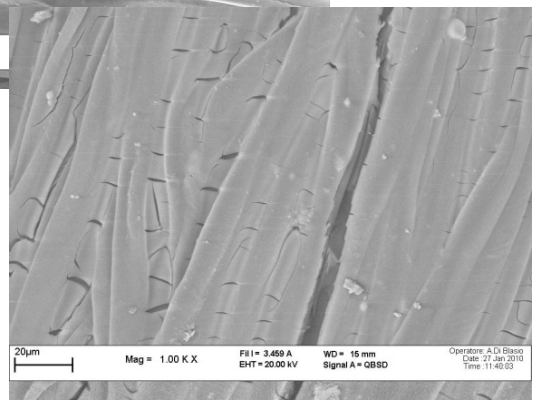


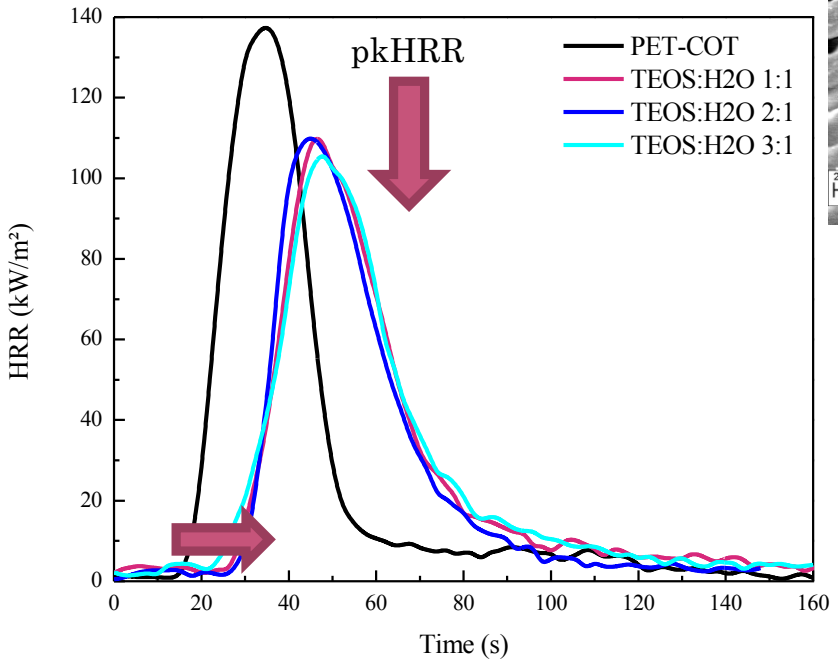
3:1

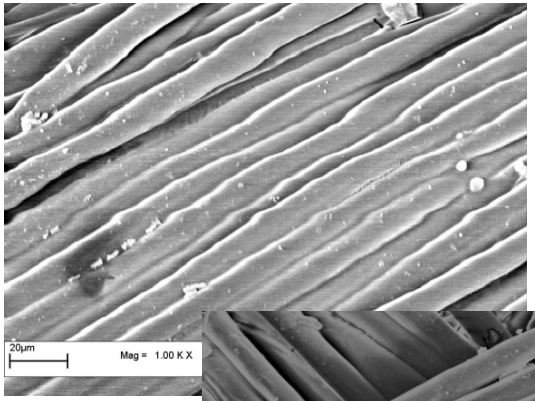
COT textiles

		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	COT	14	-	124	-	8,86
$TEOS:H_2O$	1:1	16	+2	87	-30	5,44
	2:1	10	-4	101	-18	10,10
	3:1	12	-2	81	-35	6,75

RESULTS

CONE CALORIMETRY





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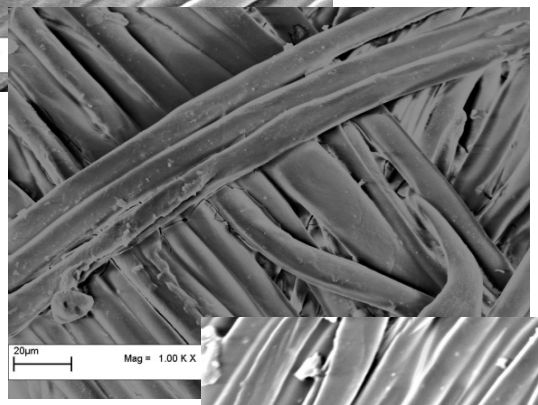

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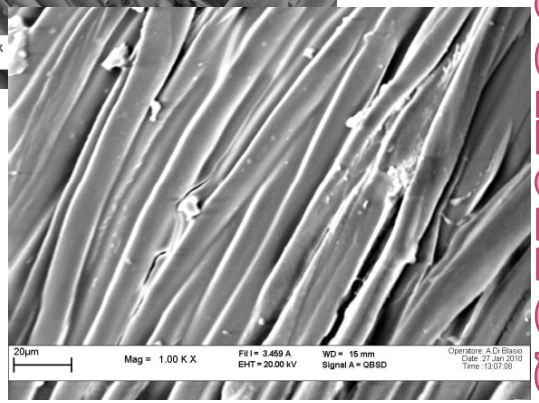


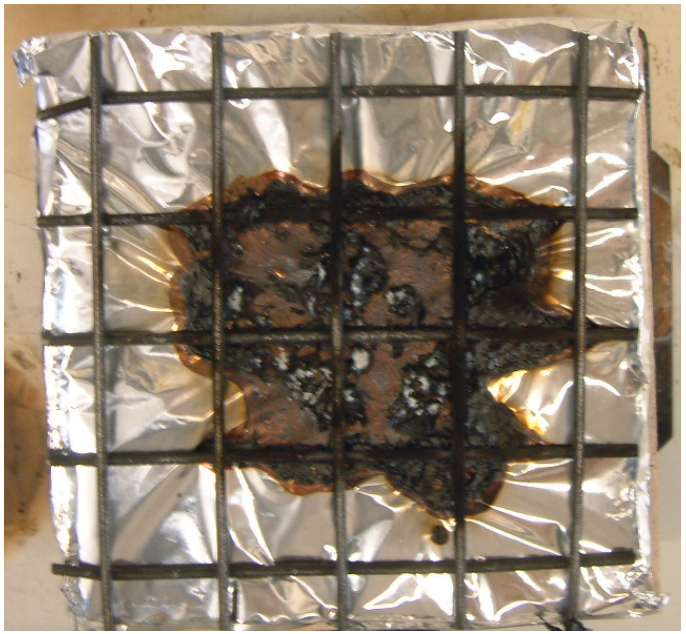
3:1

PET-COT textiles

		TTI (s)	Δ (s)	pkHRR (kW/m²)	Δ (%)	FPI
	PET-COT	14	-	138	-	9,86
$TEOS:H_2O$	1:1	26	+12	111	-19	4,27
	2:1	26	+12	110	-20	4,23
	3:1	22	+8	106	-23	4,82

TOP-DOWN vs BOTTOM-UP

	FPI	
	TOP-DOWN	BOTTOM-UP
PET	0.38	1.19
COT	4.30	5.44
PET-COT	2.97	4.27



CONCLUSIONS

- Three different preparation methodologies were carried out in order to load NPs in textile fabrics.
- The use of Plasma for the surface activation enhanced the density of NPs onto the fibers.
- By the TOP-DOWN approach, the samples with the best results from the cone calorimetry point of view were:
  - COT and PET-COT blend textiles simply immersed in a HT suspension for 30min.
  - PET and COT textiles etched and further immersed in SiO_2 suspension.
  - PET etched textiles in HT and SiO_2 suspensions.
  - Synergic effect with the use of both HT and SiO_2 NPs.

- By the BOTTOM-UP approach, the samples with the best results from the cone calorimetry point of view were only the fabrics of COT and PET-COT blend with a molar ratio TEOS:H_2O 1:1.

Articles:

- 1) "Investigation on thermal stability and fire resistance of polyester, cotton and relative blend textile fabrics subjected to sol-gel treatments", Jenny Alongi, Mihaela Ciobanu, Federico Carosio, Jennifer Tata, Giulio Malucelli, submitted to *Journal of Applied Polymer Science*.
- 2) "Influence of cold plasma on thermal and fire stability of PET and cotton textiles treated with nanometric silica and hydrotalcite", Jennifer Tata, Jenny Alongi, Alberto Frache, *on preparation*.
- 3) "Optimization of the procedure to burn textile fabrics by cone calorimeter: Part I. Combustion behavior of polyester", Jennifer Tata, Jenny Alongi, Federico Carosio, Alberto Frache, submitted to *Fire and Materials*.

Politecnico di Torino – Alessandria Branch

Thank you