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Real-Scale Upholstered Furniture Flammability and Effect of Silicone-Based Backcoating

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Introduction

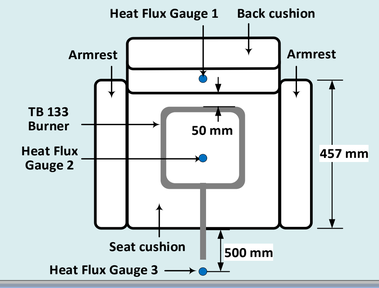
In this study, the effectiveness of a NIST developed silicone backcoating as flame-retardant in upholstered furniture has been demonstrated by full-scale smoldering and flaming tests. [1] A silicone-based elastomer filled with vinyl-silane modified aluminum-hydroxide is applied to the back of the upholstery fabric to generate an effective fire barrier with an expected benign toxicological and environmental profile. The flammability of the chair mock-ups with pristine uncoated upholstery fabric (UC) and backcoated upholstery fabric (BC) have been compared by using Cal. TB 133 [2] as flaming ignition source and NIST SRM 1196 as smoldering ignition source. Abrasion resistance and flexibility of UC and BC fabrics were also tested.

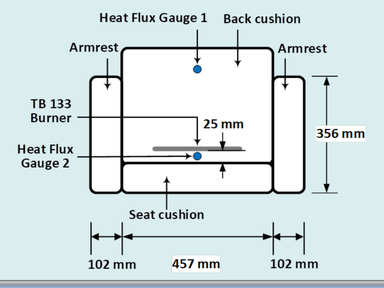
Silicone-based Back-Coated Mockup

Sample	Backcoating formulation	Area density [g/m^2]	Thickness [mm]	Flexural rigidity [μJ]
UC fabric	no backcoating	447.3 ±2.7	1.3 ±0.2	81 ±4
BC fabric	vinyl-silane modified aluminum hydroxide	813.3 ±15.9	1.5 ±0.3	287 ±57

- Foam: Cal TB 117-2013 polyurethane
- Fabrics: 100% cotton velvet (UC)
- Backcoating (BC) [1] : halogen-free silicone-based elastomer with 65% by mass of vinyl modified ATH (VSAIOH)
- Ignition method:

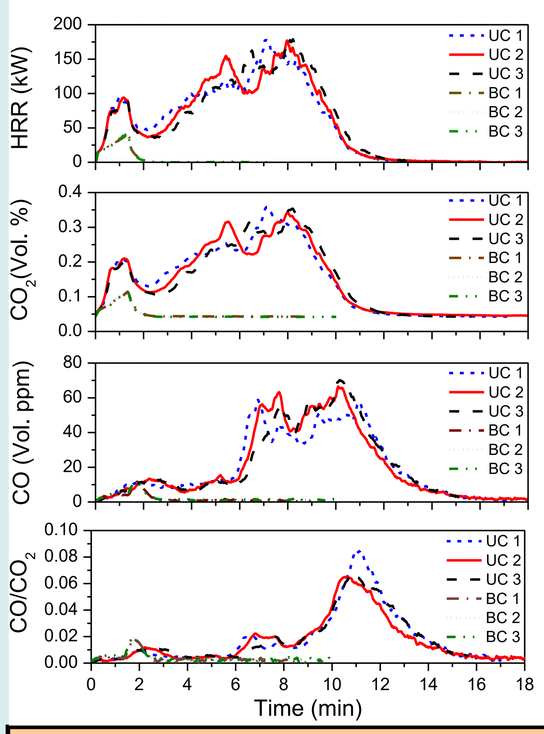
  Propane burner by Cal TB 133 with 18kW for 80 s, 1 inch above seat

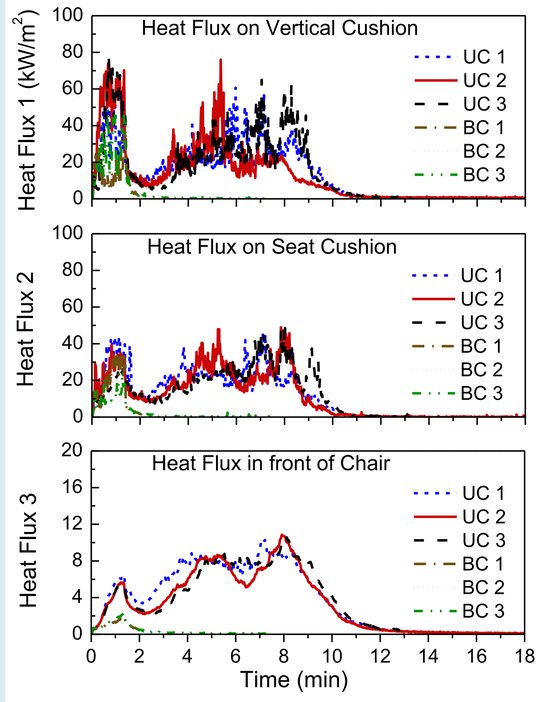


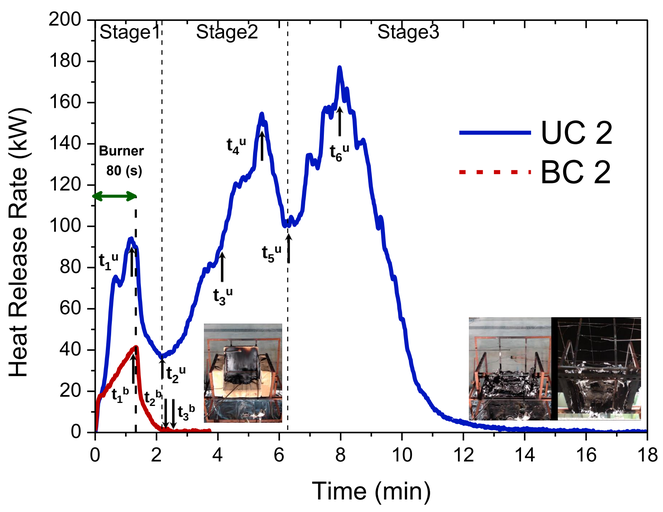


Experimental and Results

Open Flame Test on UC and BC Chair Mock-ups







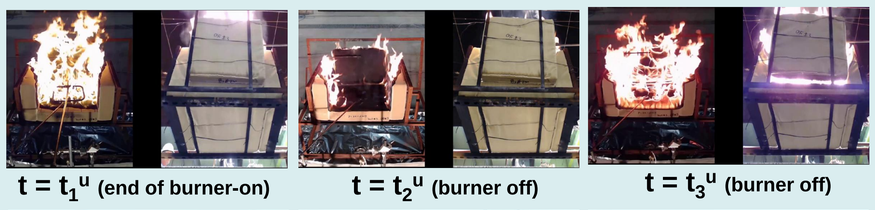
Classified stages with HRR plots of uncoated fabric chair

Stage 1: Gas-burner causes combustion of fabrics and TDI of polyurethane (for 80 s)
Stage 2: Flame spreads and more polyol occurs
Stage 3: Mockup has collapsed into a pool of flaming pyrolysis products

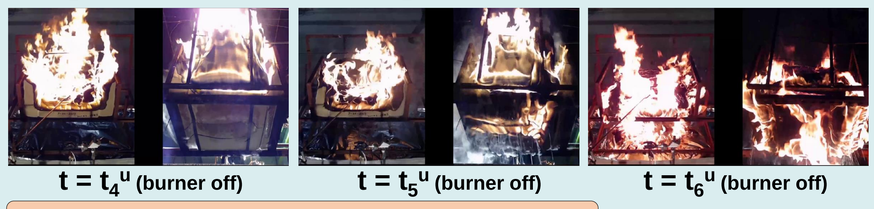
BC technology results in extraordinary reduction of flammability. BC chairs have PHRR and THR as low as 13.5 % and 2.2 % of UC chairs, respectively. Heat flux values up to about 70 kW/m^2 are measured.

Chair Fabric	Stage I				Stage II				Stage III				Total		
	$PHRR_I$ [kW]	THR_I [MJ]	ML_I [Kg]	*eff* $H_{C,I}$ [kJ/g]	$PHRR_{II}$ [kW]	THR_{II} [MJ]	ML_{II} [Kg]	*eff* $H_{C,II}$ [kJ/g]	$PHRR_{III}$ [kW]	THR_{III} [MJ]	ML_{III} [Kg]	*eff* $H_{C,III}$ [kJ/g]	THR [MJ]	TML [Kg]	*eff* $H_{C\,tot}$ [kJ/g]
UC Fabric	73.8 ±3.5	6.2 ±0.3	0.41 ±0.00	15.3 ±0.7	145 ±24.0	24.1 ±3.5	1.17 ±0.18	20.6 ±0.2	178.8 ±2.4	28.9 ±2.9	1.11 ±0.15	26.1 ±1.0	59.2 ±0.7	2.69 ±0.03	22.6 ±0.1
BC Fabric	24.2 ±0.8	1.3 ±0.1	0.15 ±0.00	8.3 ±0.5									1.3 ±0.1	0.15 ±0.00	8.3 ±0.5

Uncoated (UC) fabric Chair



t = t_1^u (end of burner-on) | t = t_2^u (burner off) | t = t_3^u (burner off)

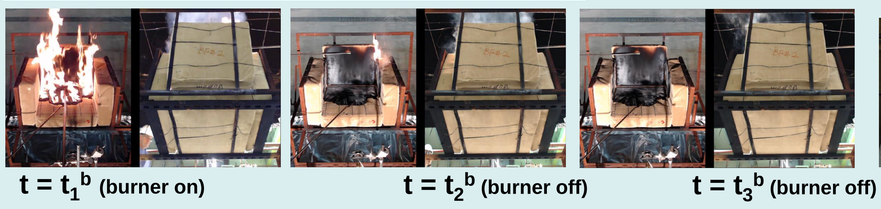


t = t_4^u (burner off) | t = t_5^u (burner off) | t = t_6^u (burner off)

UC mock-ups were fully burn by the end of test. (Left)

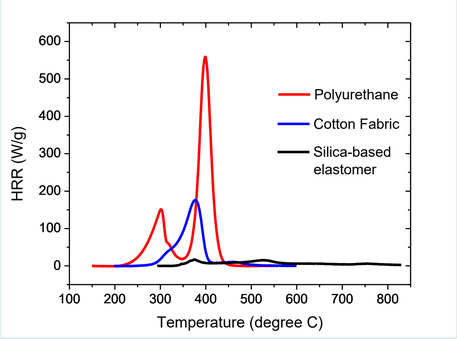
On the contrary, in BC mock-ups foam combustion was negligible (see below).

Back-Coated (BC) fabric Chair



t = t_1^b (burner on) | t = t_2^b (burner off) | t = t_3^b (burner off)

Micro-Scale Combustion Calorimetry and Abrasion Resistance Tests



Sample	THR [kJ/g]	PHRR [W/g]
Polyurethane foam	26.1 ±0.06	555.9 ±5.65
Velvet (100% cotton) fabric	10.3 ±0.08	178.0 ±2.82
Sylgard 65% VSAIOH	3.6 ±0.44	17.0 ±0.92

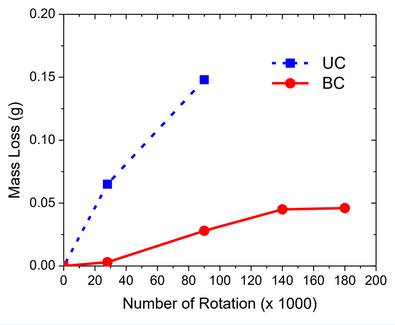
$$k \cdot THR_{Full\text{-}Test} = THR_{Cal.} \quad \text{(Eq. 1)}$$

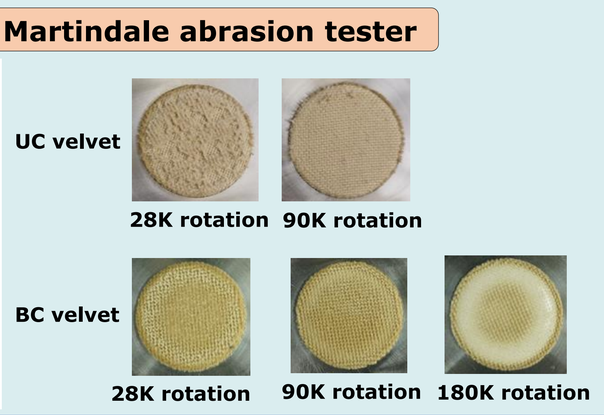
$$eff\ H_{c\ Full\text{-}test} = THR_{Full\text{-}Test} / ML_{Full\text{-}Test} \quad \text{(Eq. 2)}$$

$$THR_{Cal.} = ML_{PUF,Full\text{-}Test} \cdot H_{c\ PUF,MCC} + ML_{Fabric,Full\text{-}Test} \cdot H_{c\ Fabric,MCC} \quad \text{(Eq. 3)}$$

***Factor k* ≈ 0.999 ± 0.006 for UC fabric chair**

Abrasion resistance test by Martindale abrasion tester





Conclusion

The results show that the BC fabric allows to achieve an unusual all-in-one solution for flaming and smoldering combustion that improves durability without affecting the aesthetics or the comfort of the chair.

References

[1] M. Zammarano et al., Adv Mater Interfaces 3(23) (2016).
[2] California TB 133 Flammability Test Procedure, Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, North Highlands, CA, 1991.