Supplementary Information

Development and demonstration of highly potent flame-retardant cotton fabric.

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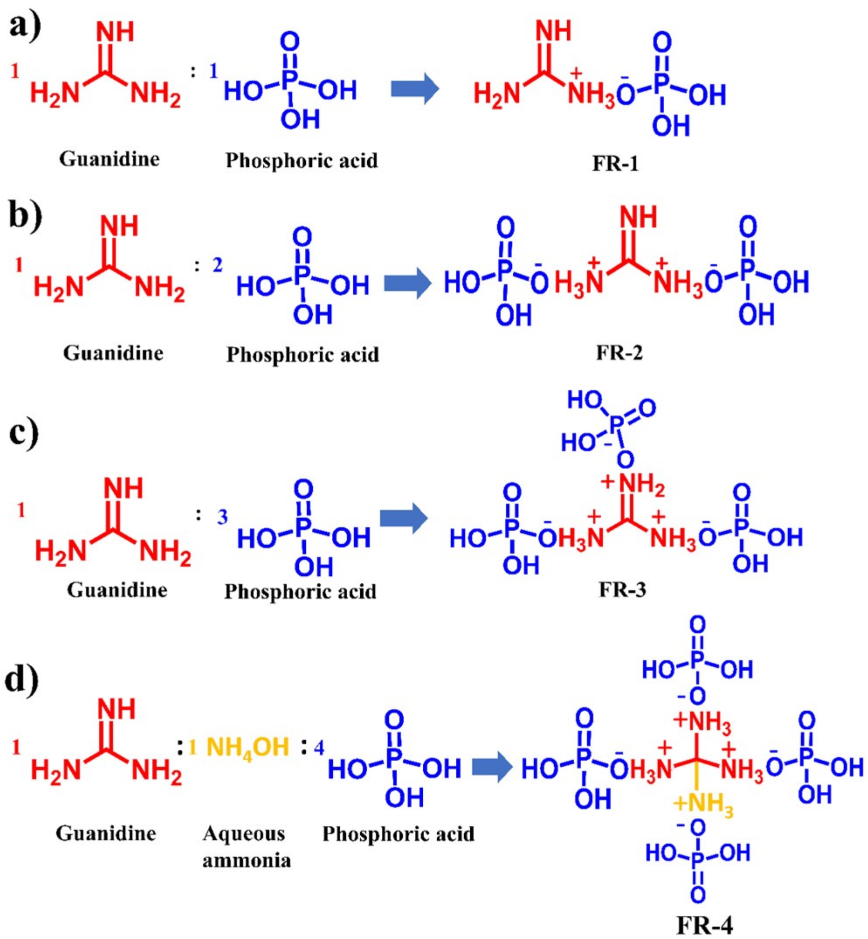

Figure S1. Synthesis and chemical structure of a) FR-1, b) FR-2, c) FR-3, and d) FR-4 composite.

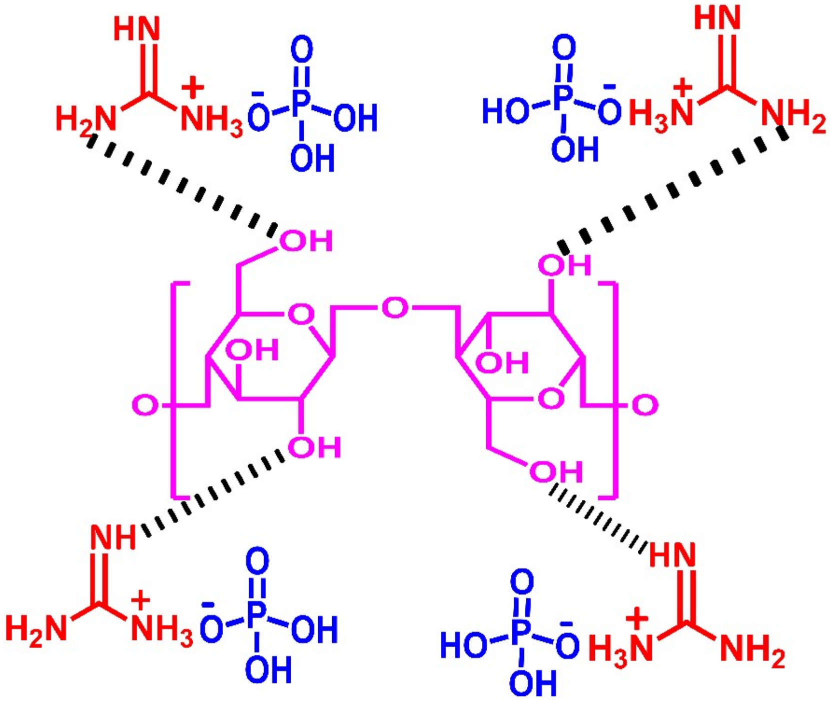

Figure S2: Ionic interaction of FR-1 composite with cotton fabric (FR-1@cotton fabric).

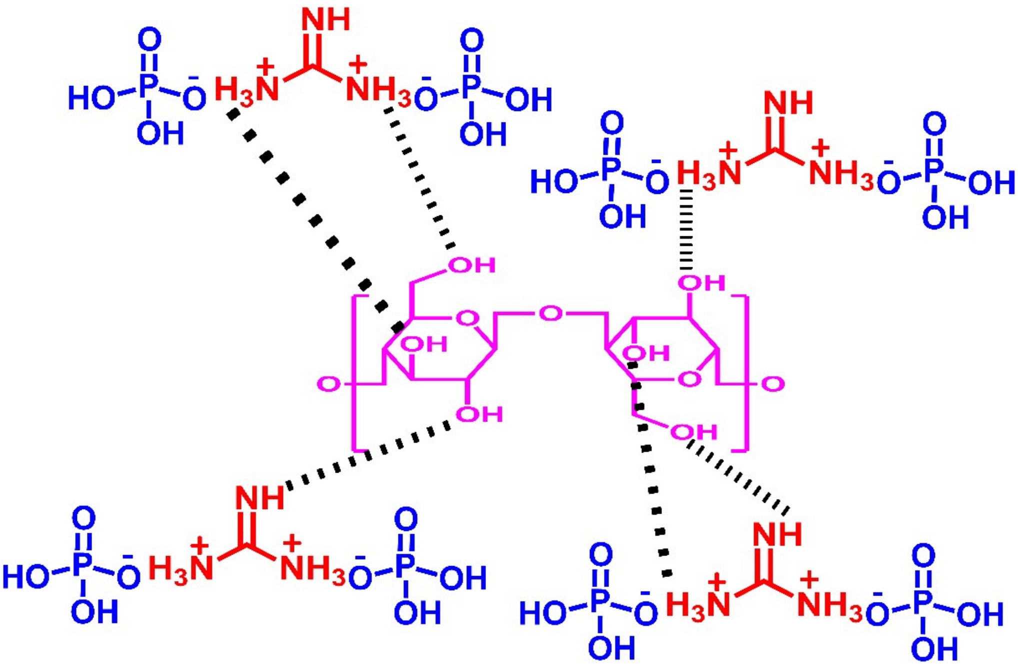

Figure S3: Ionic interaction of FR-2 composite with cotton fabric (FR-2@cotton fabric).

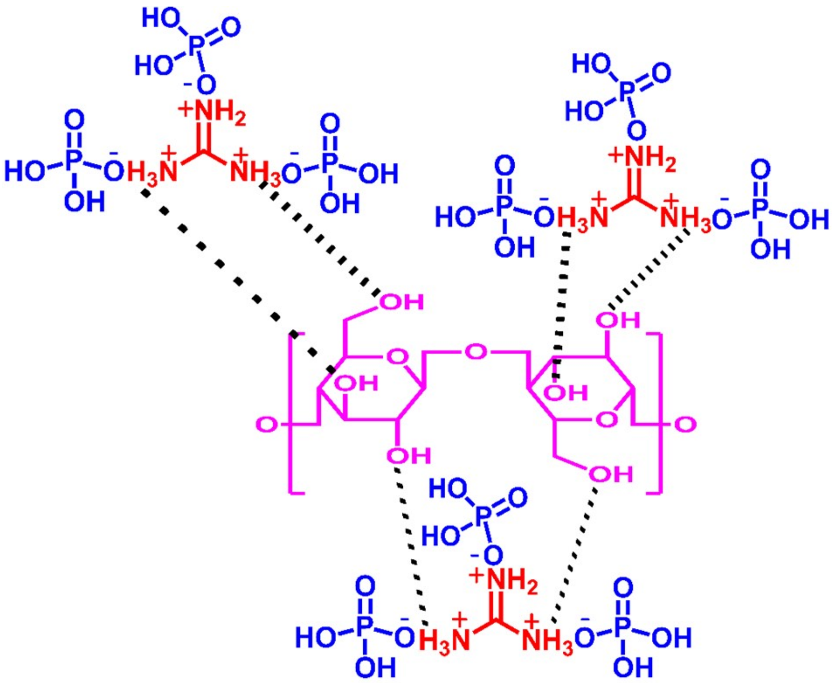

Figure S4: Ionic interaction of FR-3 composite with cotton fabric (FR-3@cotton fabric).

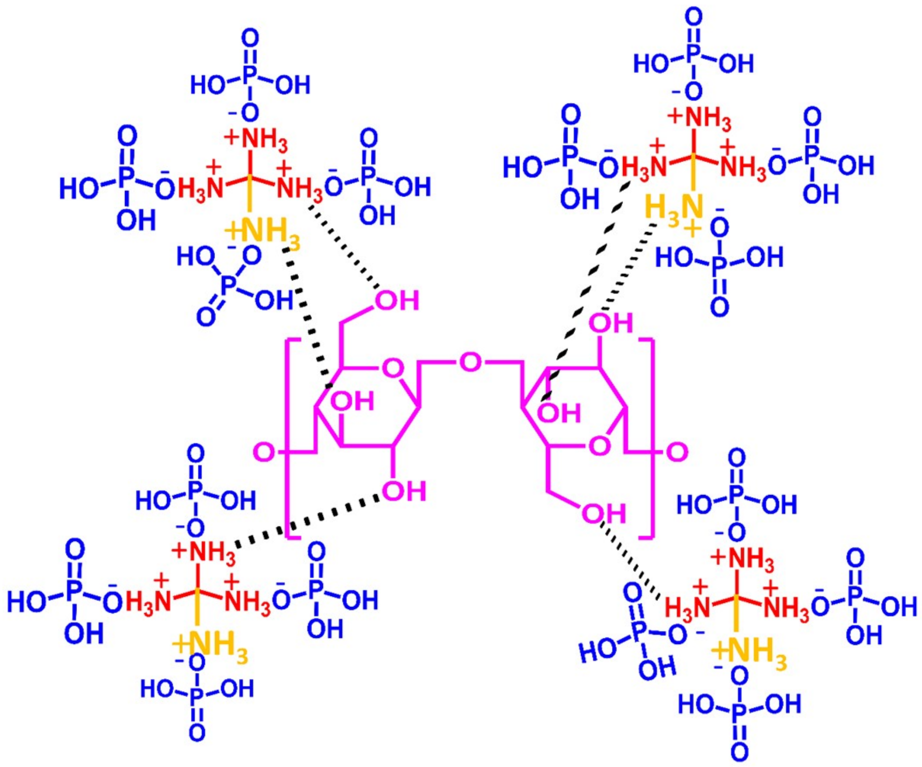

Figure S5: Ionic interaction of FR-4 composite with cotton fabric (FR-4@cotton fabric).

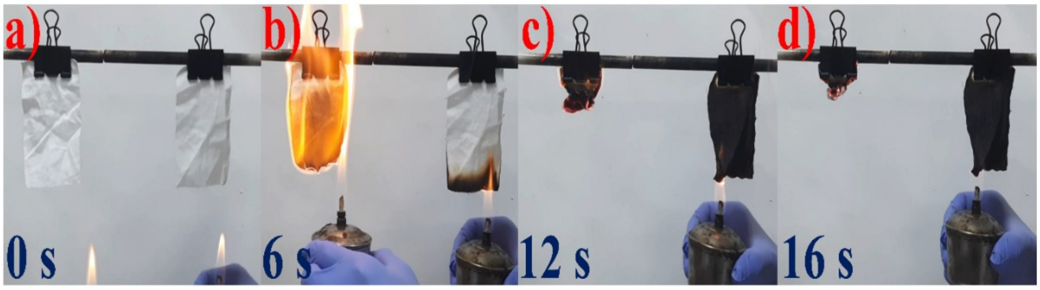

Figure S6: Digital photograph of the flame-retardant test of control cotton fabric coated with a-d) guanidine hydrochloride.

In **Figure S6** the guanidine hydrochloride coated cotton fabric catches fire and sustains up to 16 s it may be because of presence of nitrogen functionality. Meanwhile, the control cotton fabric, shrinkage was observed and after flame test, the fabric losses its strength and become brittle. Whereas the blank cotton fabric was burn completely within 14 s.

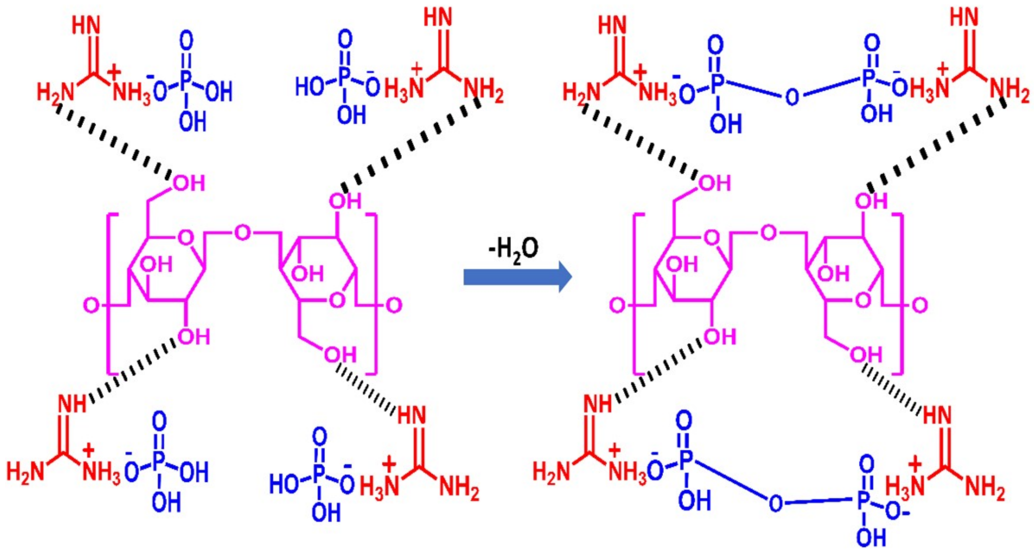

Figure S7: Schematic representation for the proposed dehydration of the FR-1 by forming phosphoanhydride by intramolecular as well as intermolecular reaction.

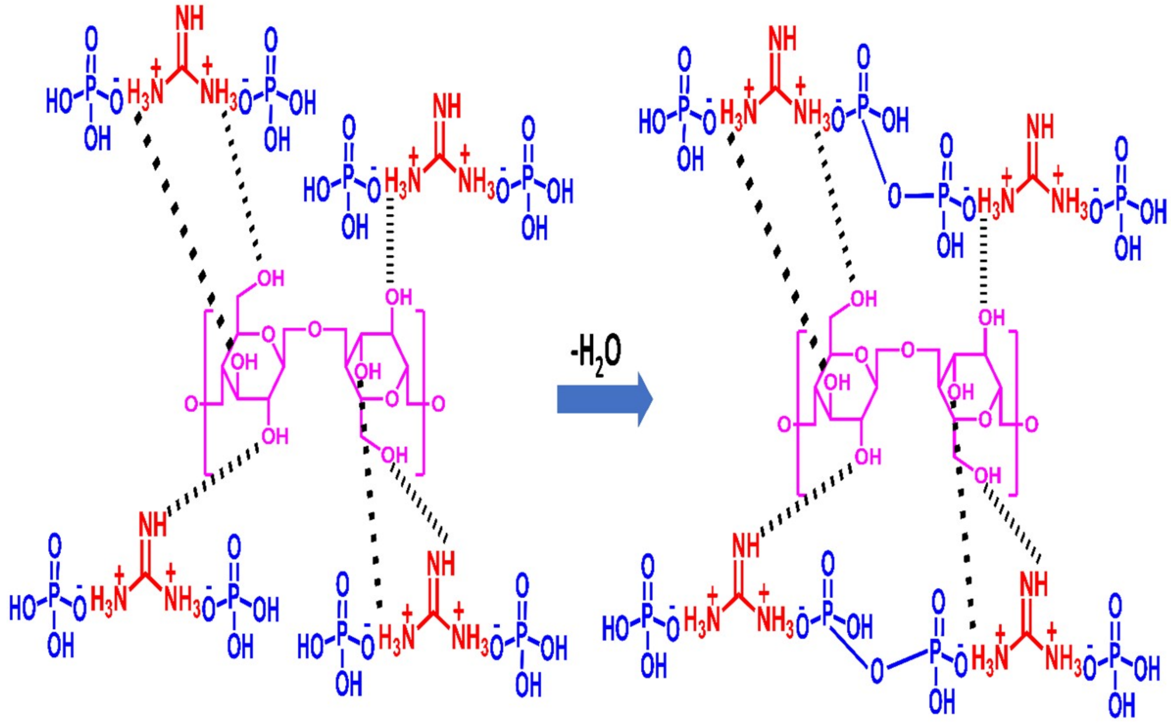

Figure S8: Schematic representation for the proposed dehydration of the FR-2 by forming phosphoanhydride by intramolecular as well as intermolecular reaction.

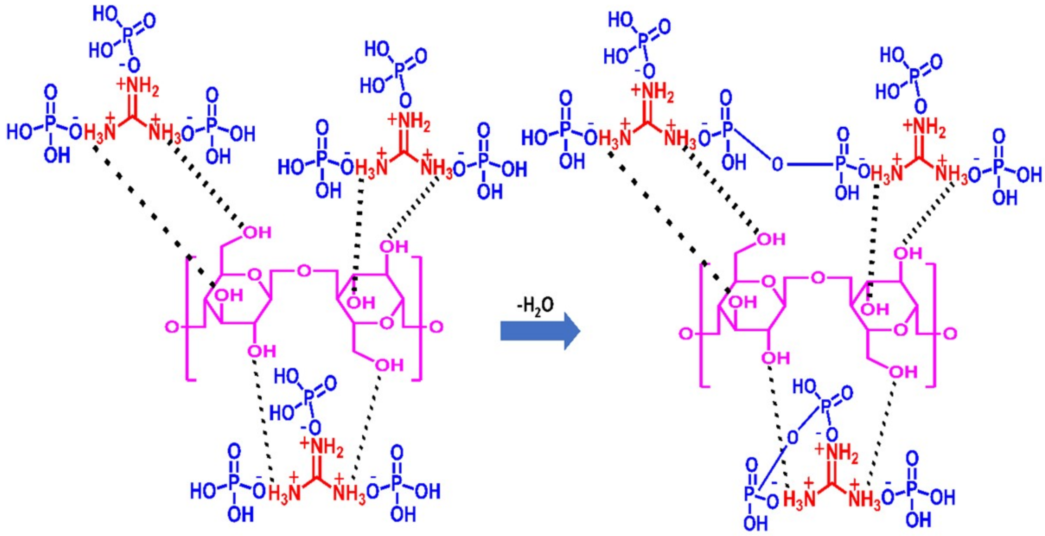

Figure S9: Schematic representation for the proposed dehydration of the FR-3 by forming phosphoanhydride by intramolecular as well as intermolecular reaction.

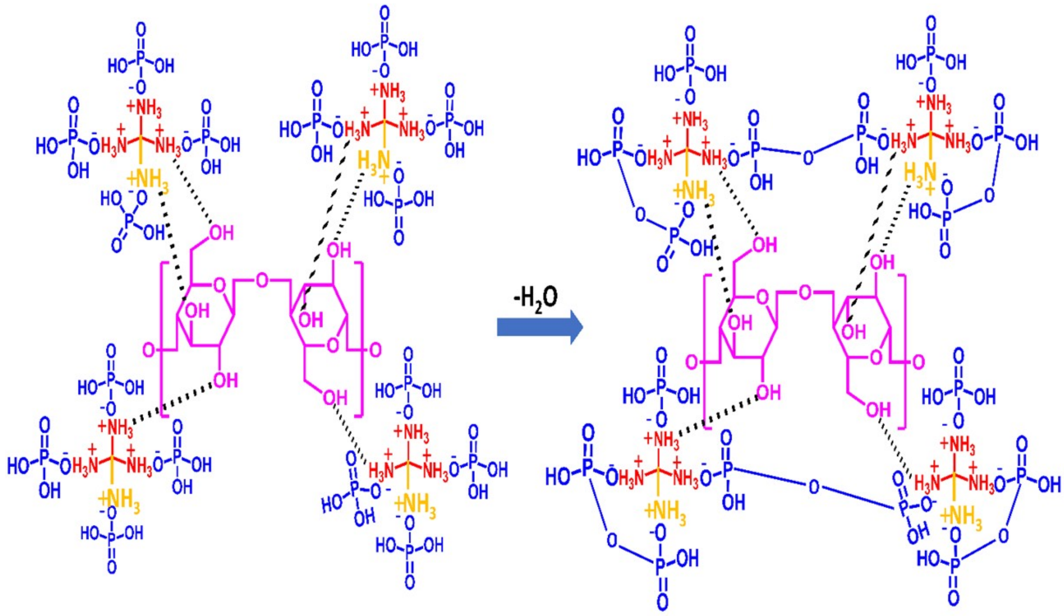

Figure S10: Schematic representation for the proposed dehydration of the FR-4 by forming phosphoanhydride by intramolecular as well as intermolecular reaction.

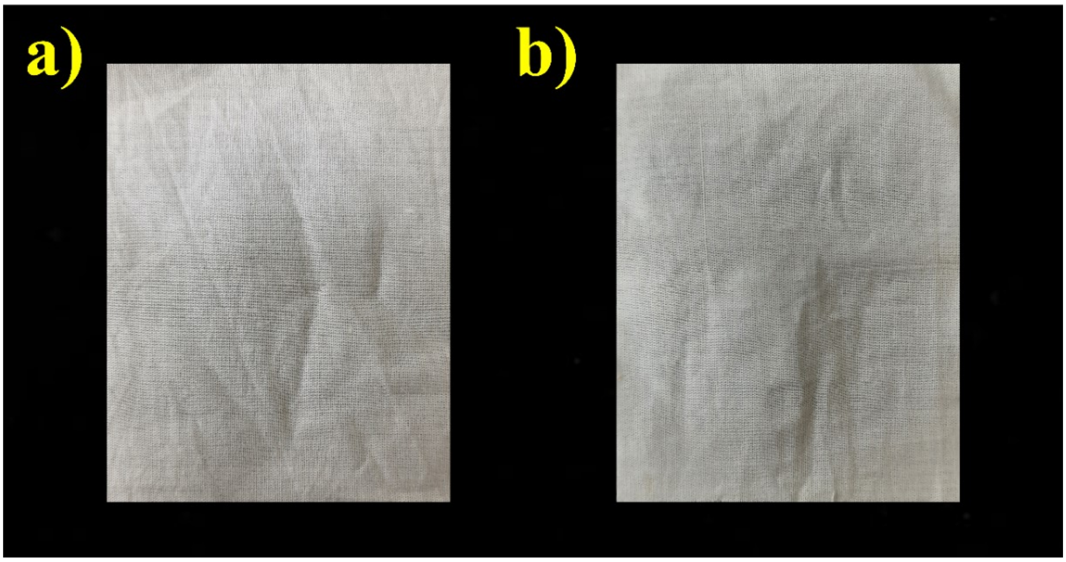

Figure S11. Digital photograph of (a) Blank sample, (b) FR-4@cotton fabric

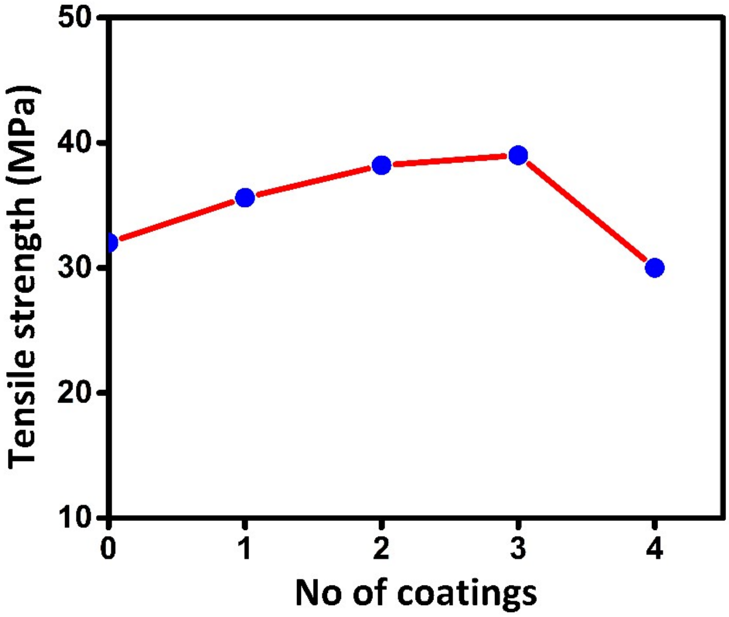

Figure S12. Tensile strength of FR-4@Cotton fabric

The durability of FR-4@Cotton fabric, we examined with tensile strength test. The tensile strength of FR-4@Cotton fabric was measured by using reported method in which we observed that the trend of tensile strength of FR-4@Cotton fabric was increased. The maximum tensile strength was observed of FR-4@Cotton fabric for 3rd no of coating and after that the tensile strength of FR-4@Cotton was gradual decreased. The tensile strength results of FR-4@Cotton fabric is summarized in **Figure S12**.

Table S1: The Weight % and stochiometric feed ratio of carbon, oxygen, nitrogen and phosphorous of FR-1 to FR-4 material based on XPS data

Sr. No.	Name of FR Composite material	Carbon		Oxygen		Nitrogen		Phosphorous	
		Weight %	Stochiometric ratio	Weight %	Stochiometric ratio	Weight %	Stochiometric ratio	Weight %	Stochiometric ratio
1	FR-1	12	0.99 (~1)	44	3.82 (~4)	32	2.89 (~3)	12	0.99 (~1)
2	FR-2	9	0.85 (~1)	56	7.92 (~8)	21	2.84 (~3)	14	1.89 (~2)
3	FR-3	8	0.78 (~1)	60	11.95 (~12)	16	2.85 (~3)	16	2.95 (~3)
4	FR-4	6	0.77 (~1)	64	16.02 (~16)	15	3.78 (~4)	15	3.85 (~4)

Table No. S2: LOI (%) value of synthesized material coated cotton fabric with respect to no of coating.

No of coating	Guanidine + PA (1:1) (FR-1@cotton fabric)	Guanidine + PA (1:2) (FR-2@cotton fabric)	Guanidine + PA (1:3) (FR-3@cotton fabric)	Guanidine + NH_4OH + PA (1:1:4) (FR-4@cotton fabric)
1st Coating	35	40	48	50
2nd Coating	37	42	50	52
3rd Coating	40	46	51	53
4th Coating	43	48	53	55

*The LOI of blank cotton fabric was 16%.

Table No. S3: Comparative data of synthesized material with reported material

Sr. No.	Flame retardant material	LOI	Reference
1.	Thiourea, phosphoric acid, PCl_5, ethanolamine, urea	48.2	[1]
2.	Formaldehyde, melamine, anhydrous H_3PO_3, urea	43.0	[2]
3.	alkylammonium func-tional silsesquioxane, phytic acid	29	[3]
4.	Glycerol, phosphoric acid, urea	33.7	[4]
5.	Diethyl chlorophosphite, Methacrylamide, Triethylamine	30.2	[5]
6.	Casein, dimethyl phosphite, formaldehyde, phosphoric acid (H_3PO_3)	41.6	[6]
7.	Guanidine, phosphoric acid (FR-1)	43	**This Work**
8.	Guanidine, phosphoric acid (FR-2)	48	**This Work**
9.	Guanidine, phosphoric acid (FR-3)	53	**This Work**
10.	Guanidine hydrochloride, ammonium hydroxide, Phosphoric acid (FR-4)	55	**This Work**

Table No. S4: Vertical flammability data of control cotton fabric with flame retardant material coated cotton fabric.

Flammability parameter	Blank Cotton fabric	Guanidine + PA (1:1) (FR-1@cotton fabric)	Guanidine + PA (1:2) (FR-2@cotton fabric)	Guanidine + PA (1:3) (FR-3@cotton fabric)	Guanidine + NH_4OH + PA (1:1:4) (FR-4@cotton fabric)
Occurring flashing over the surface	Yes	No	No	0	0
Burning with flame time (s)	17	0	0	0	0
Burning with afterglow time (s) After flame stop	0	0	0	0	0
Total burning time (s) (Flame time + after glow time)	17	0	0	0	0
Char length (cm)	Nil	5	4	3.5	3

Table No S5: Comparative data of as synthesized material with respect to LOI, VFT and observation observed in spirit lamp test.

Sr. No.	FR material	Composition	LOI (%)	VFT (cm)	Observation observed in Spirit lamp test
1.	FR-1@cotton fabric	Guanidine + Phosphoric acid (1:1)	43	5	Acted as a good FR material but shrink the cotton fabric and sustained up to 327 s.
2.	FR-2@cotton fabric	Guanidine + Phosphoric acid (1:2)	48	4	Improved FR efficiency and performed effective FR material but shrink the cotton fabric and sustained up to 424 s.
3.	FR-3@cotton fabric	Guanidine + Phosphoric acid (1:3)	53	3.5	Improved FR efficiency and performed efficient FR material but shrink the cotton fabric and sustained up to 470 s.
4.	FR-4@cotton fabric	Guanidine + ammonium hydroxide Phosphoric acid (1:1)	55	3	Improved FR efficiency and performed as a highly effective FR material without changing its initial shape and sustain up to 492 s.

Table S6: Wash fastness Data of FR-4@Cotton fabric without and with Binder/FR-4@Cotton fabric before and after washing % weight loss

Sr. No.	Sample	Before Washing			After 1st Washing			% weight loss
		Weight (gm)	LOI (%)	Char length (cm)	Weight (gm)	LOI (%)	Char length (cm)	
1	FR-4@Cotton Fabric	1.1006	55	3	0.7526	45.5	5	31.61
2	Binder/FR-4@Cotton Fabric	1.1021	54.5	3.2	0.9695	52.1	3.6	12.03

The wash fastness data of synthesized FR-4@Cotton fabric was tested by ISO2 method.[29] FR-4@Cotton fabric was washed with 5 g/L of soap solution with liquor ratio 50:1 at 50 ^{o}C for 45 min, after rinsed properly with water and dried it in air. We observed maximum ~31.61 % weight loss in case of FR-4@Cotton fabric after washing. Whereas, only ~12.03 % of weight loss is observed, by using Saraprint AC as a binder.[29]

Table No S7: Add on % data of FR-1 material on cotton fabric

Sr. No.	**Weight of cotton fabric (g)**	**No. of coatings**	**Weight FR-1@cotton cloth (g)**	**FR-1 Load (%)**	**Results after exposure to similar flame (Spirit lamp test)**
1.	0.640	1st Coating	0.743	~16	Served as a moderate FR material towards cotton fabric.
2.	0.638	2nd Coating	0.759	~19	Improved FR efficiency and showed good FR performance towards cotton fabric.
3.	0.638	3rd Coating	0.781	~22	Improved FR efficiency and performed effective FR performance towards the cotton fabric.
4.	0.639	4th Coating	0.806	~26	Improved FR efficiency and performed excellent FR performance towards cotton fabric.

Table No S8: Add on % data of FR-2 material on cotton fabric

Sr. No.	**Weight of cotton fabric (g)**	**No. of coatings**	**Weight FR-2@cotton cloth (g)**	**FR-2 Load (%)**	**Results after exposure to similar flame (Spirit lamp test)**
1.	0.639	1st Coating	0.749	~17	Served as a good FR material towards cotton fabric.
2.	0.640	2nd Coating	0.769	~20	Improved FR efficiency and showed effective FR performance towards cotton fabric.
					Improved FR efficiency and performed

3.	0.638	3rd Coating	0.785	~23	excellent FR performance towards the cotton fabric.
4.	0.636	4th Coating	0.815	~28	Improved FR efficiency and performed outstanding FR performance towards cotton fabric.

Table No S9: Add on % data of FR-3 material on cotton fabric

Sr. No.	Weight of cotton fabric (g)	No. of coatings	Weight FR-3@cotton cloth (g)	FR-3 Load (%)	Results after exposure to similar flame (Spirit lamp test)
1.	0.639	1st Coating	0.755	~18	Served as a effective FR material towards cotton fabric.
2.	0.640	2nd Coating	0.781	~22	Improved FR efficiency and showed excellent FR performance towards cotton fabric.
3.	0.638	3rd Coating	0.798	~25	Improved FR efficiency and performed very effective FR performance towards the cotton fabric.
4.	0.638	4th Coating	0.832	~30	Improved FR efficiency and performed outstanding FR performance towards cotton fabric.

Table No S10: Add on % data of FR-4 material on cotton fabric

Sr. No.	Weight of cotton fabric (g)	No. of coatings	Weight FR-4@cotton cloth (g)	FR-4 Load (%)	Results after exposure to similar flame (Spirit lamp test)
1.	0.640	1st Coating	0.769	~20	Served as a excellent FR material towards cotton fabric.
2.	0.639	2nd Coating	0.794	~24	Improved FR efficiency and showed very effective FR performance towards cotton fabric.
3.	0.640	3rd Coating	0.827	~29	Improved FR efficiency and performed outstanding FR performance towards the cotton fabric.
4.	0.641	4th Coating	0.853	~33	Improved FR efficiency and performed magnificent FR performance towards cotton fabric.

Table No. S11. Bending length and stiffness data of FR@Cotton fabric.

Sr. No.	**Name of FR@Cotton fabric**	**Whiteness**		**Whiteness**
		Warp	Weft	
1.	Control	1.5	1.4	127
2.	FR-1@Cotton fabric	1.7	1.6	128.159
3.	FR-2@Cotton fabric	1.8	1.7	131.884
4.	FR-3@Cotton fabric	1.9	1.8	132.074

5.	FR-4@Cotton fabric	2.1	2.0	132.300

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