Supplementary Material

Novel Polyurethanes Based on Recycled Polyethylene Terephthalate: Synthesis, Characterization, and Formulation of Binders for Environmentally Responsible Rocket Propellants

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Table of Contents

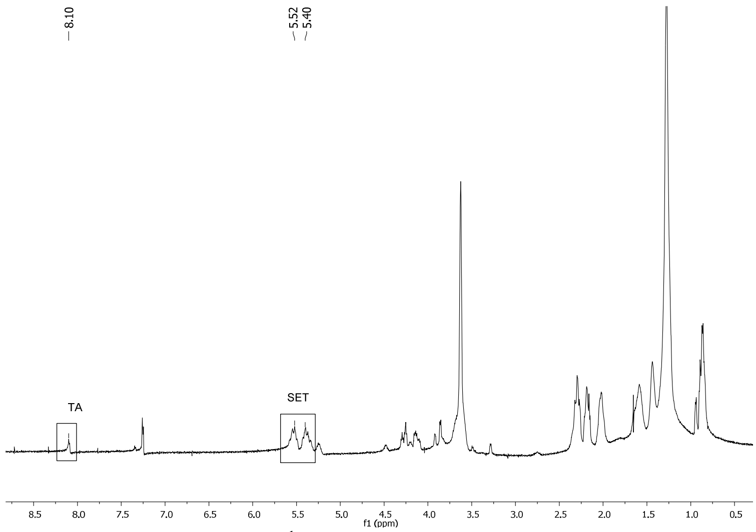


Figure S1. – ^{1}H- NMR spectra for SRP1.

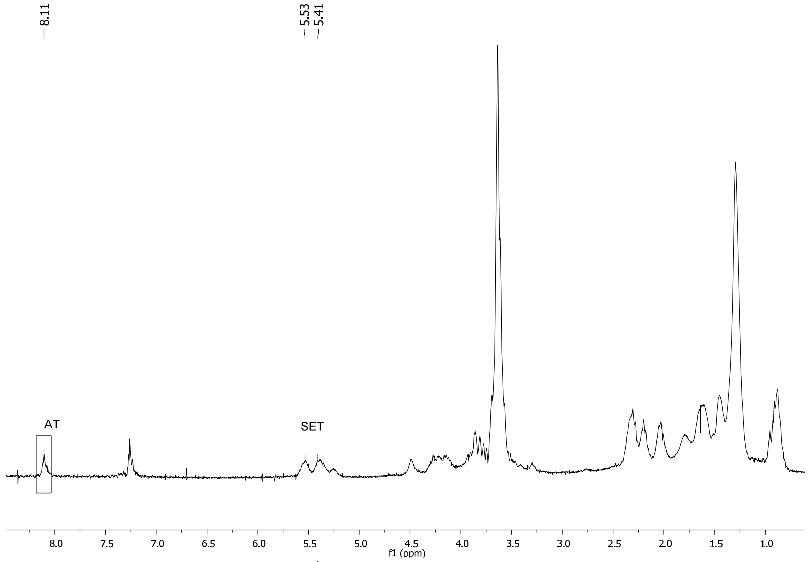


Figure S2. – ^{1}H- NMR spectra for SRP2.

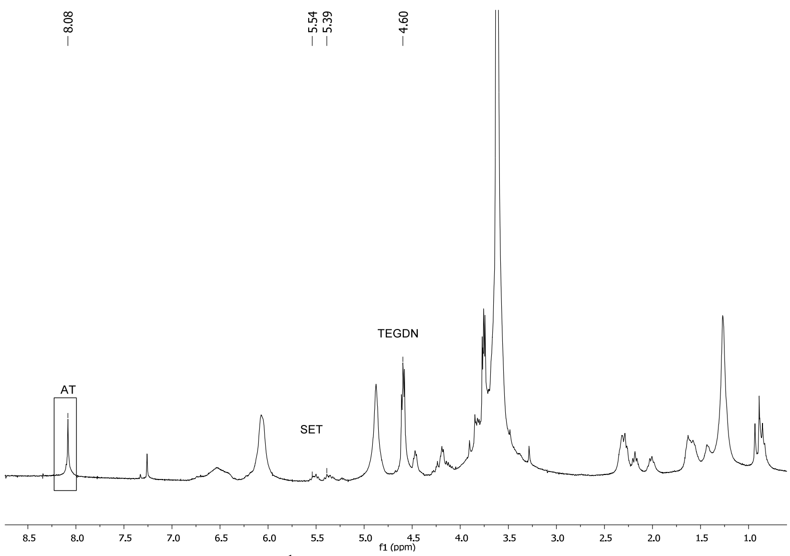


Figure S3. – ^{1}H- NMR spectra for SRP1T2.

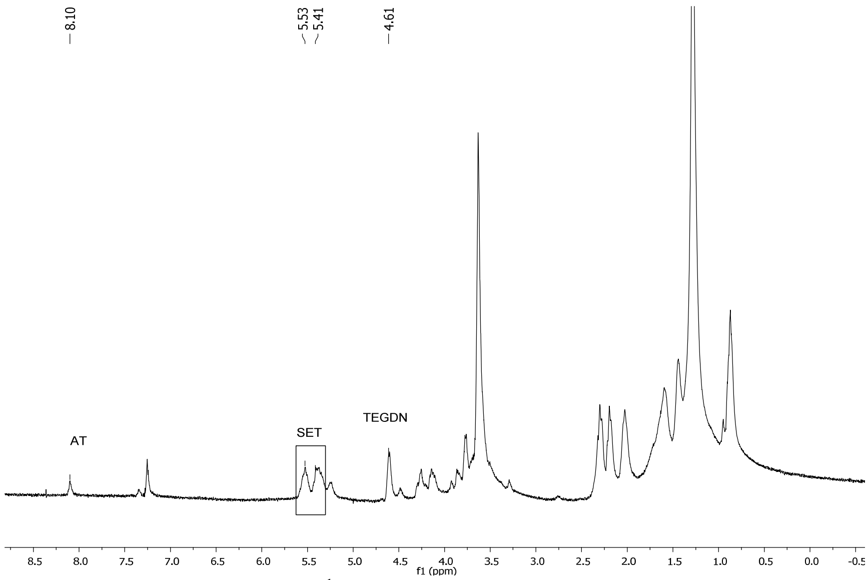


Figure S4. – [1]H- NMR spectra for SRP2T2.

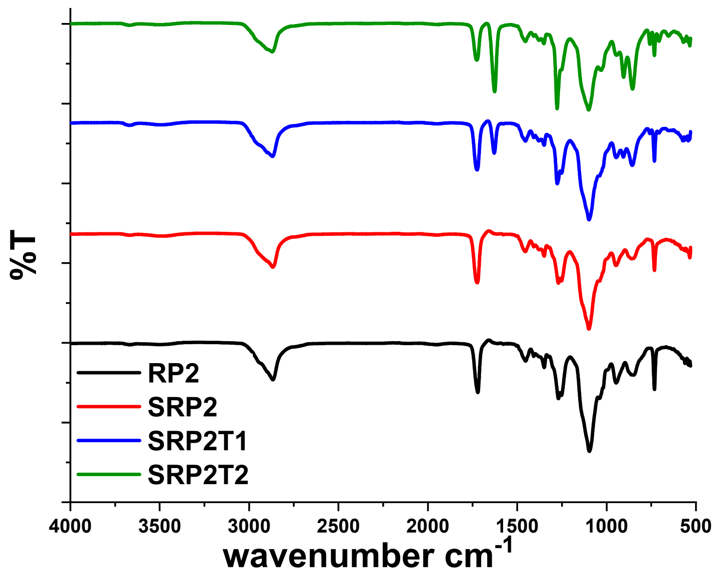


Figure S5. – FT-IR spectra of polyurethanes based on RP2.

Figure S6. – Brief table comprising the aspect, properties, and the time of curing for each polyurethane binder.

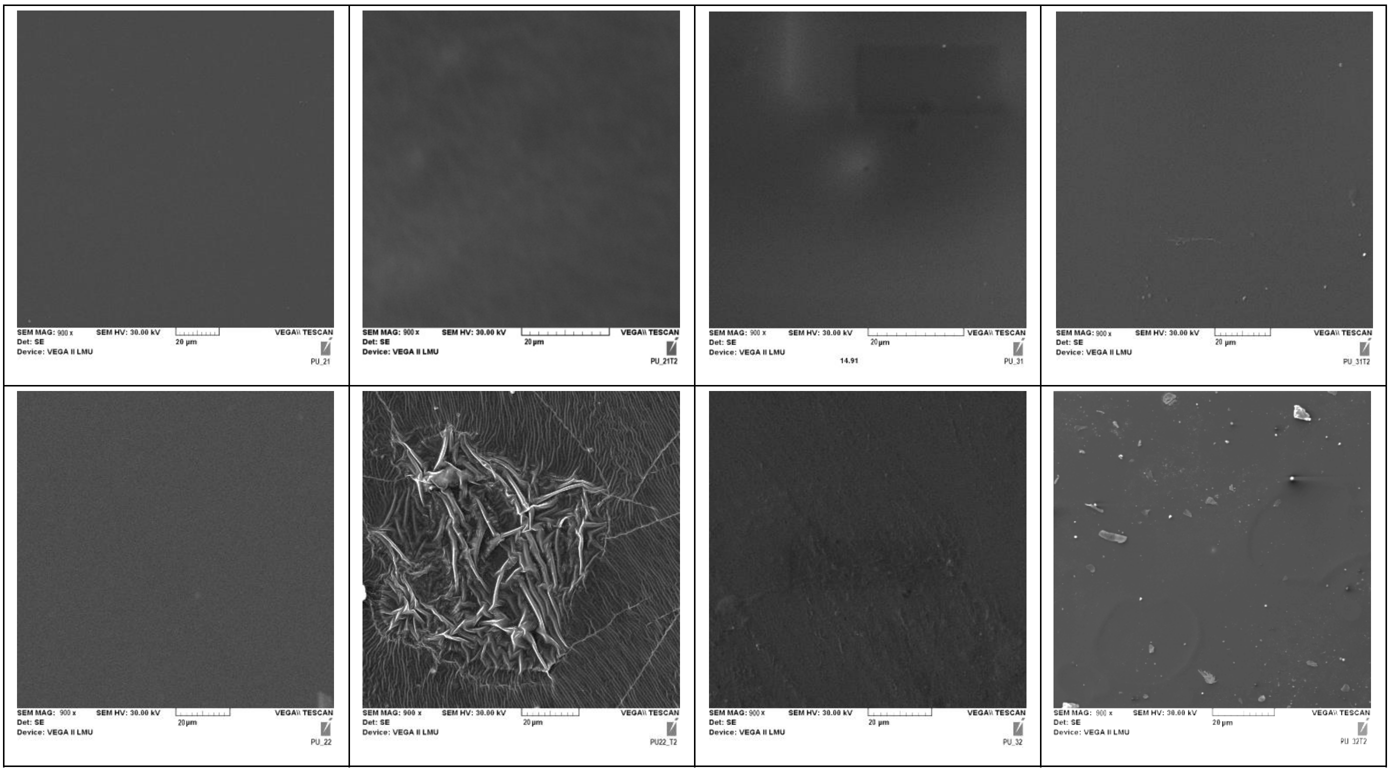


Figure S7. – SEM images of polyurethanes formulations based on RP1 and RP2 (with and without TEGDN).

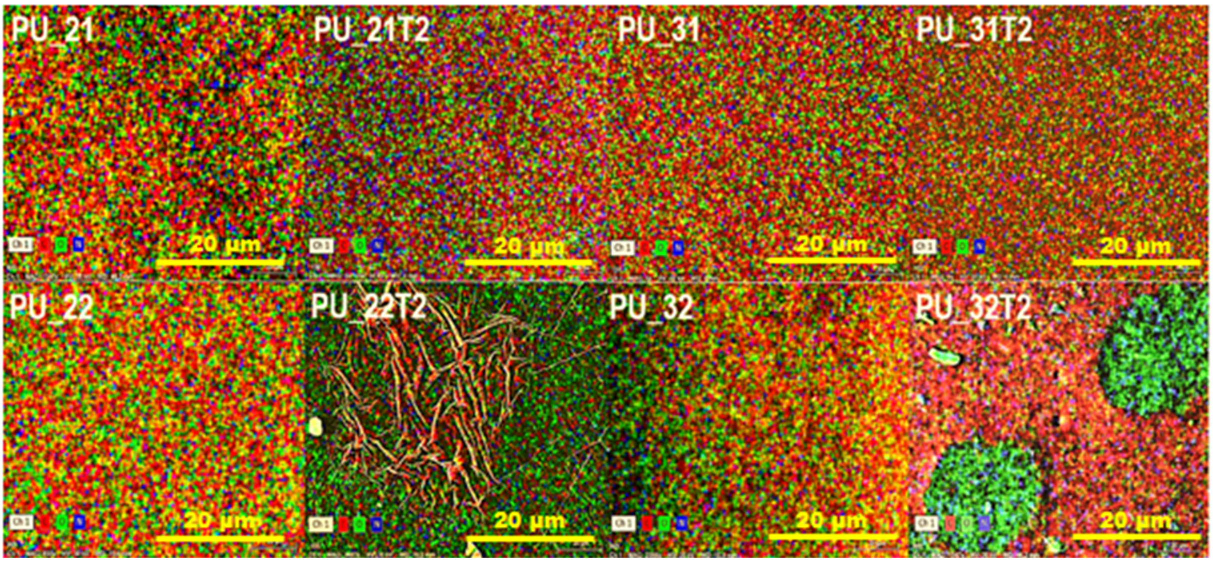


Figure S8. EDX mapping of the polyurethane formulations from S7.

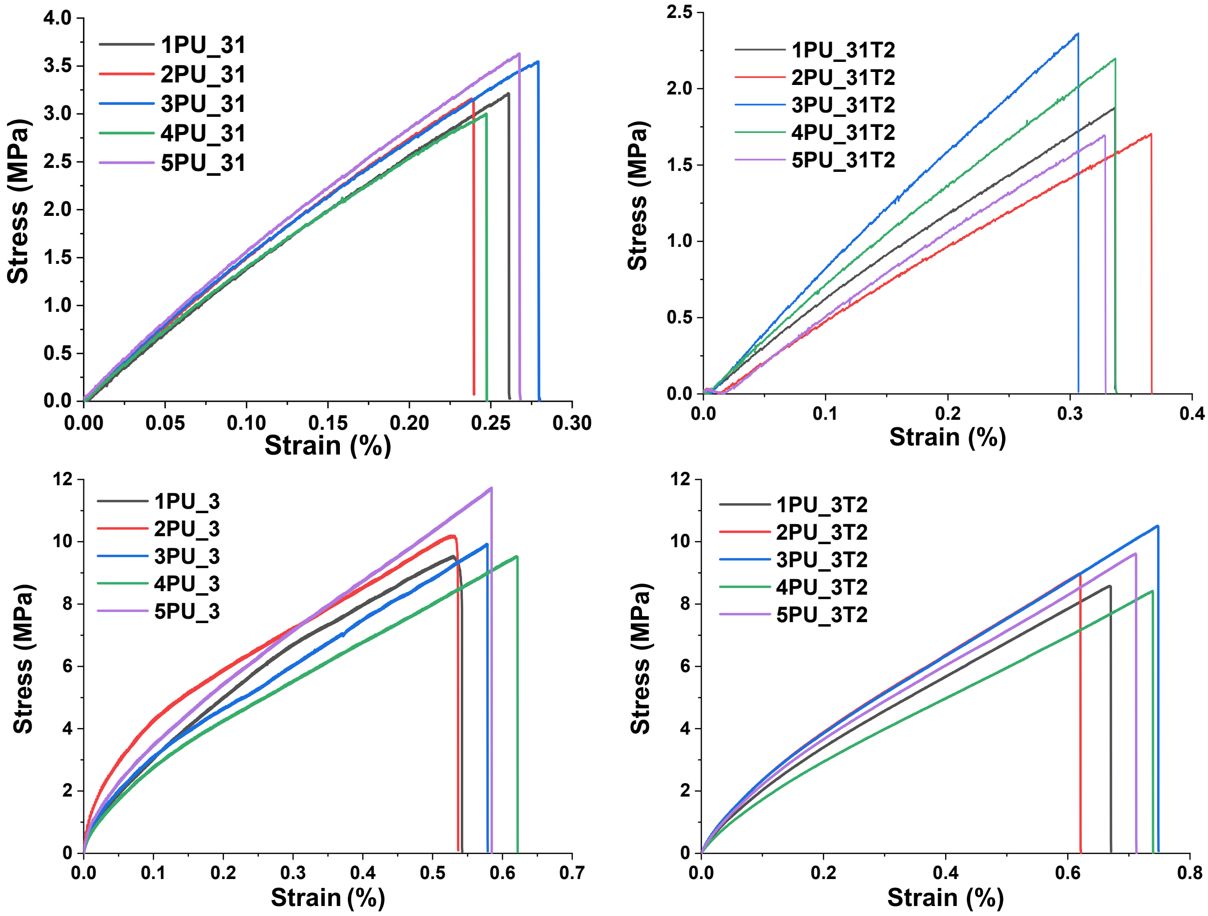


Figure S9. – Tensile stress-strain plots for PU formulations.

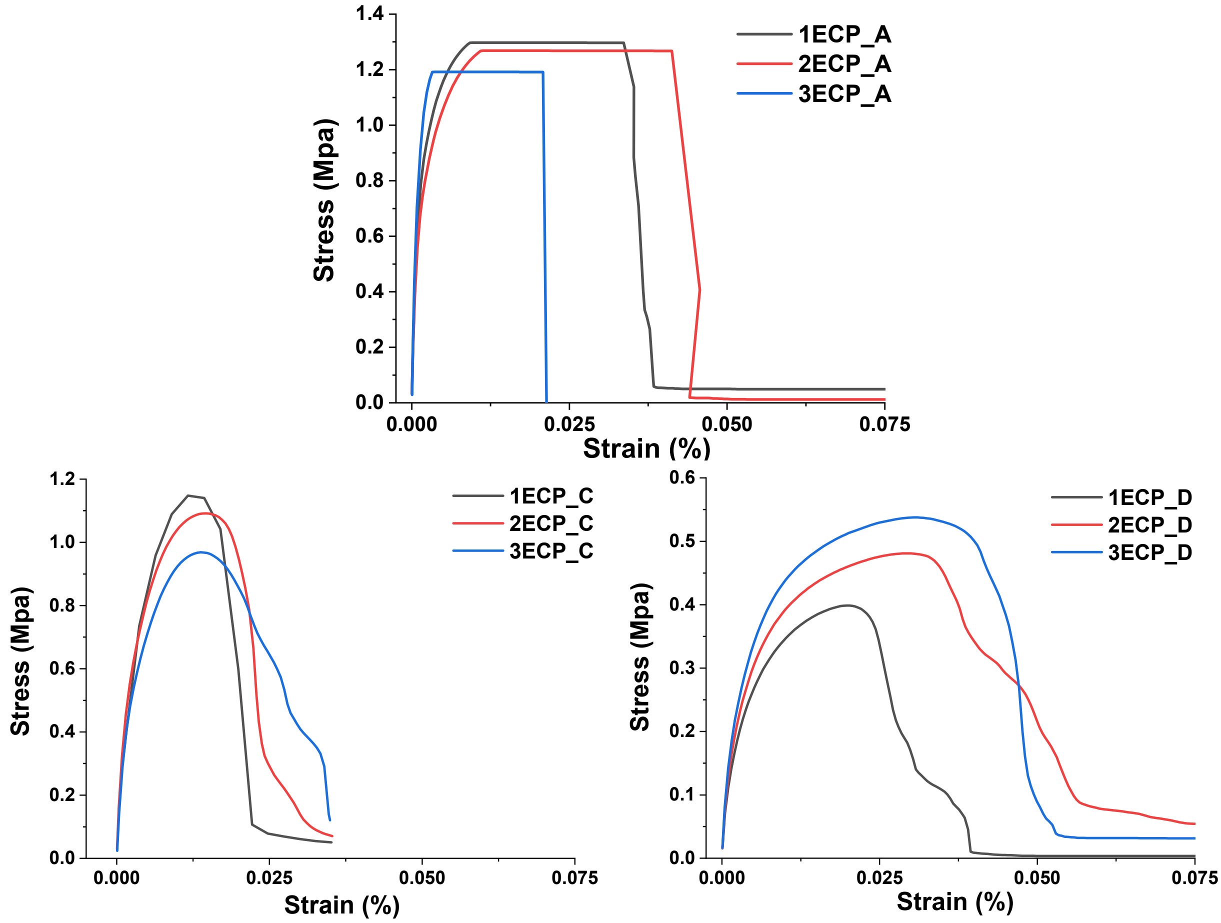


Figure S10. – Tensile stress-strain plots for composite propellant formulations.

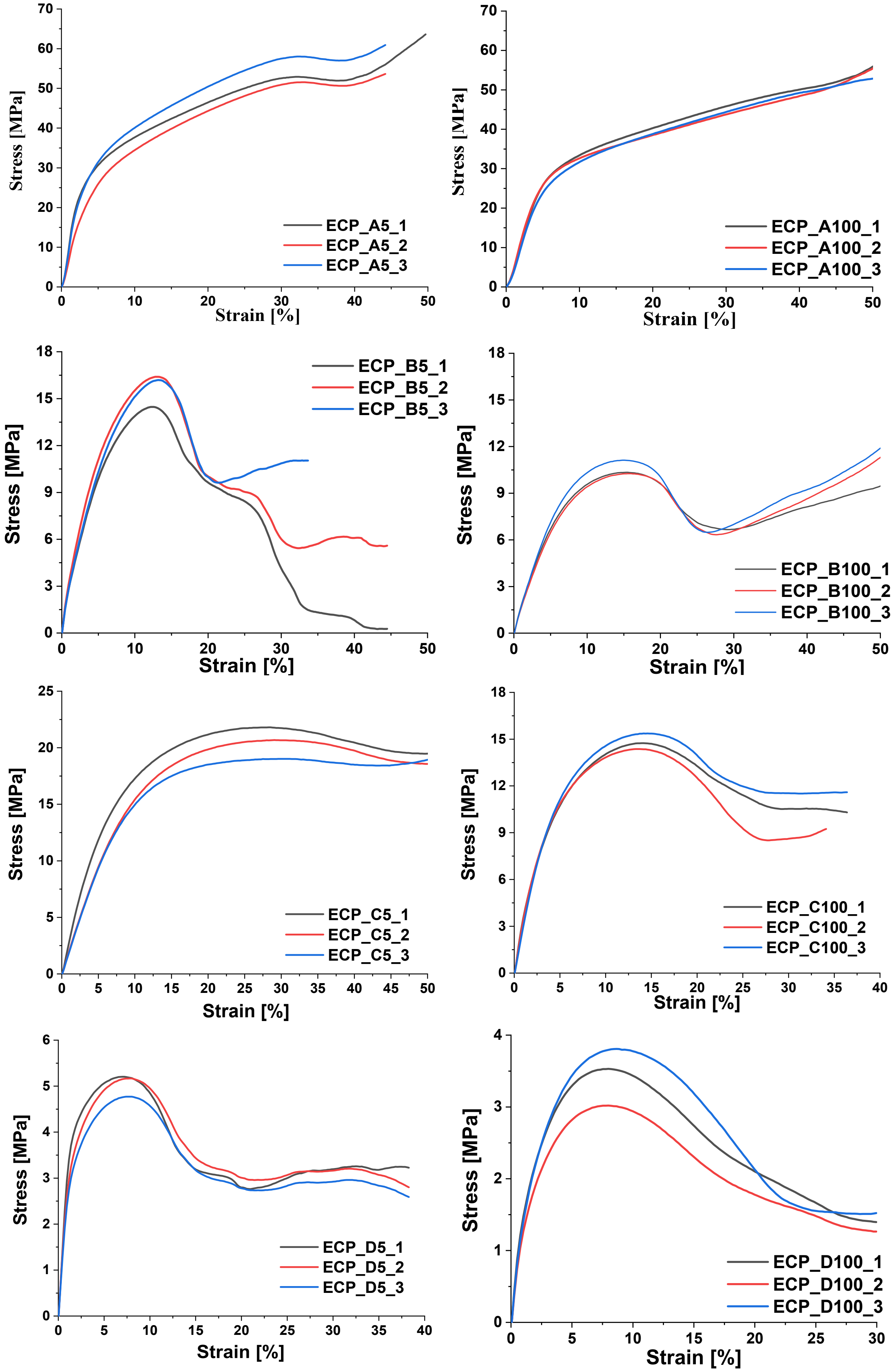
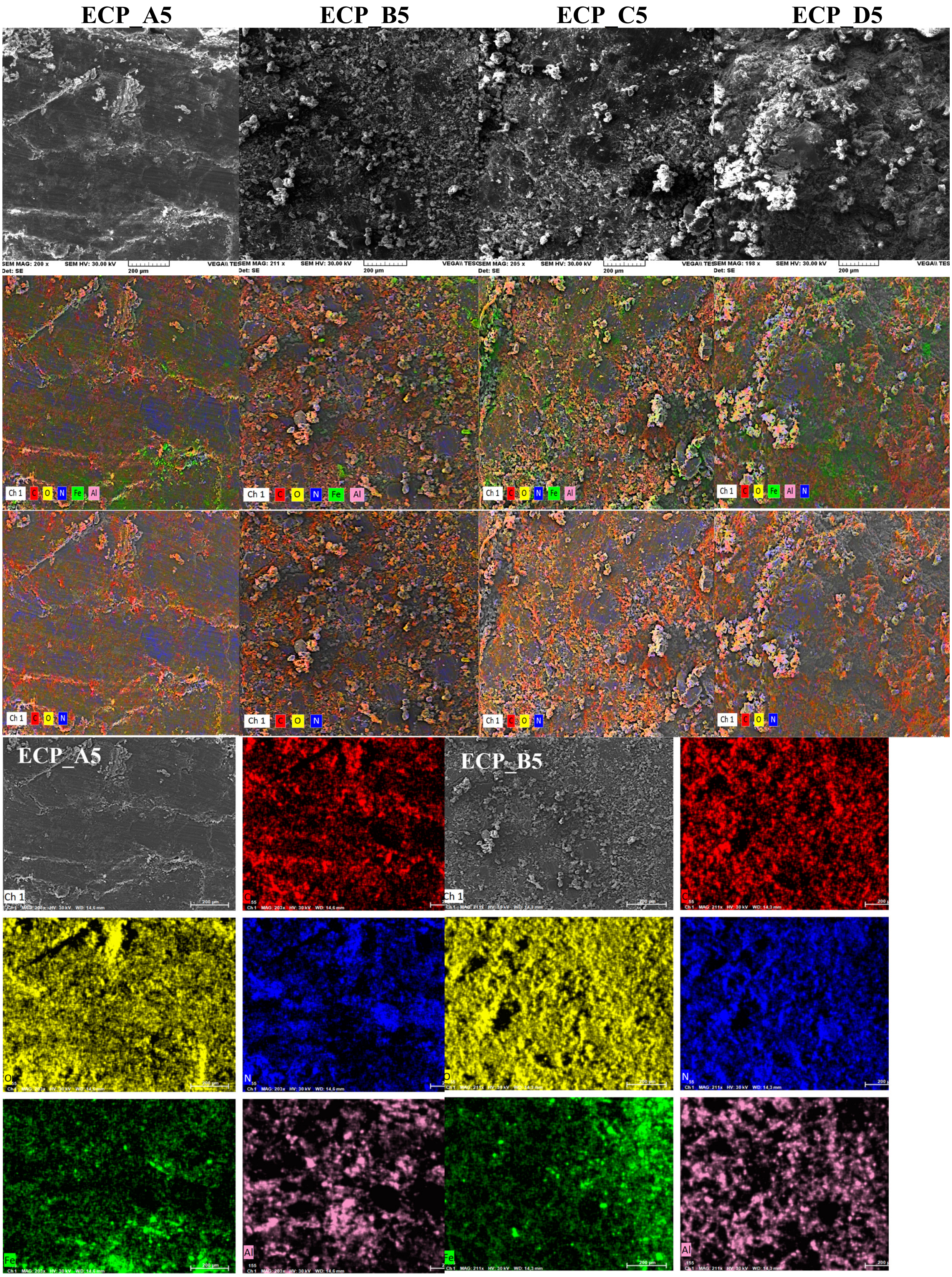


Figure S11. – Compression tests plots for composite formulations.


ECP_A5
ECP_B5
ECP_C5
ECP_D5
Ch 1
C
O
N
Fe
Al
ECP_A5
ECP_B5

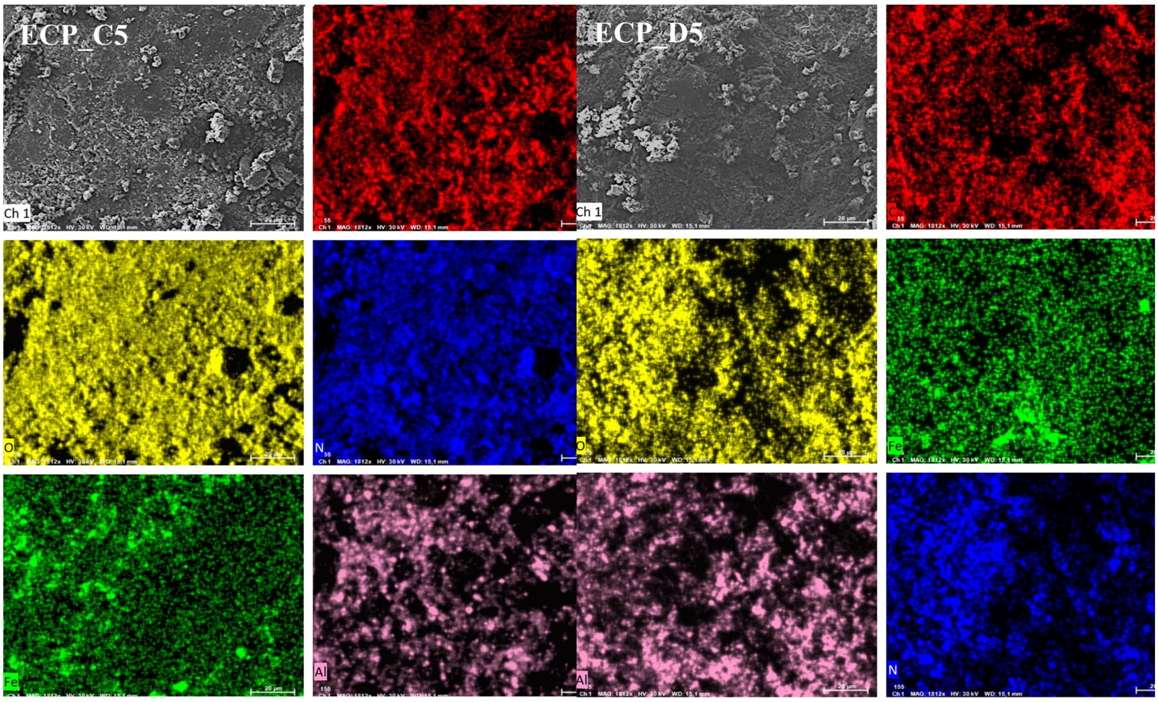


Figure S12. – SEM-EDX images of composite propellant formulations.

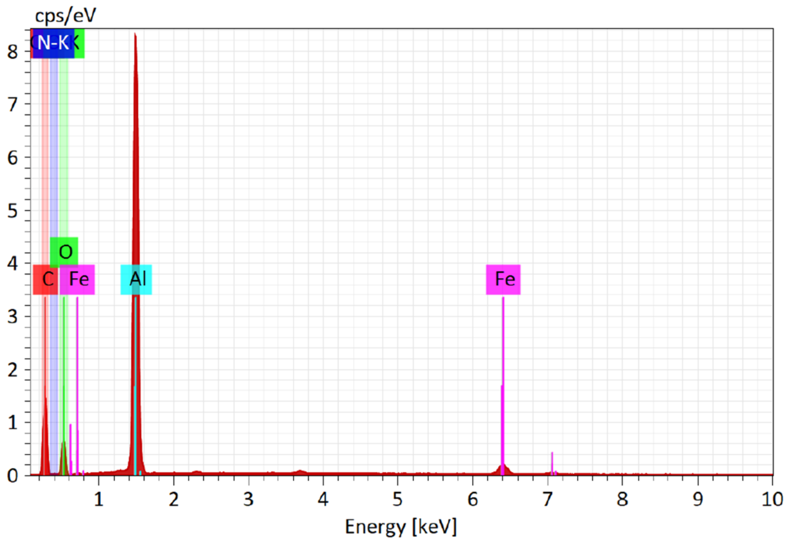


Figure S13. – EDX spectra for oxidizer-free composite formulations .

Table S1. Weight and atomic composition of oxidizer-free composite formulations.

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. error [%] (1 sigma)
Carbon	6	52579	119,49	54,32	65,62	6,53	5,47
Oxygen	8	25392	47,09	21,41	19,42	2,59	5,50
Aluminium	13	426660	41,21	18,74	10,08	1,74	4,21
Nitrogen	7	1755	9,77	4,44	4,60	0,59	6,00
Iron	26	20749	2,39	1,09	0,28	0,05	2,18
		Sum	**219,96**	**100,00**	**100,00**		

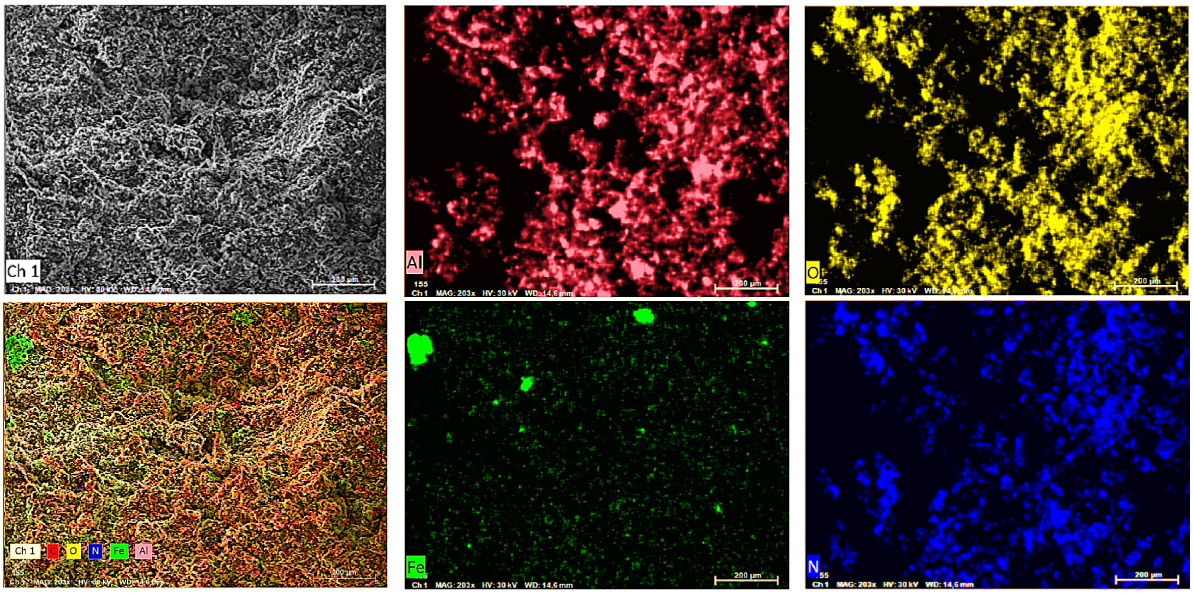


Figure S14. – SEM-EDX images of binder-free solid mixture.

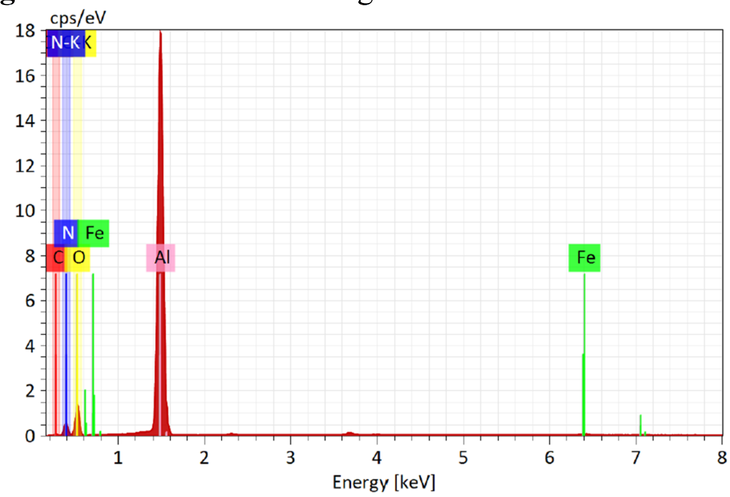


Figure S15 – EDX spectra for binder-free solid mixture.

Table S2. Weight and atomic composition of free binder solid mixture.

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. error [%] (1 sigma)
Aluminium	13	917245	58,74	40,03	28,82	2,30	3,91
Oxygen	8	52068	56,50	38,58	43,88	2,57	5,42
Nitrogen	7	21162	30,96	21,10	27,21	1,69	5,47
Carbon	6	0	0,00	0,00	0,00	0,00	4,36
Iron	26	5482	0,54	0,29	0,09	0,01	3,09
		Sum	**146,75**	**100,00**	**100,00**		

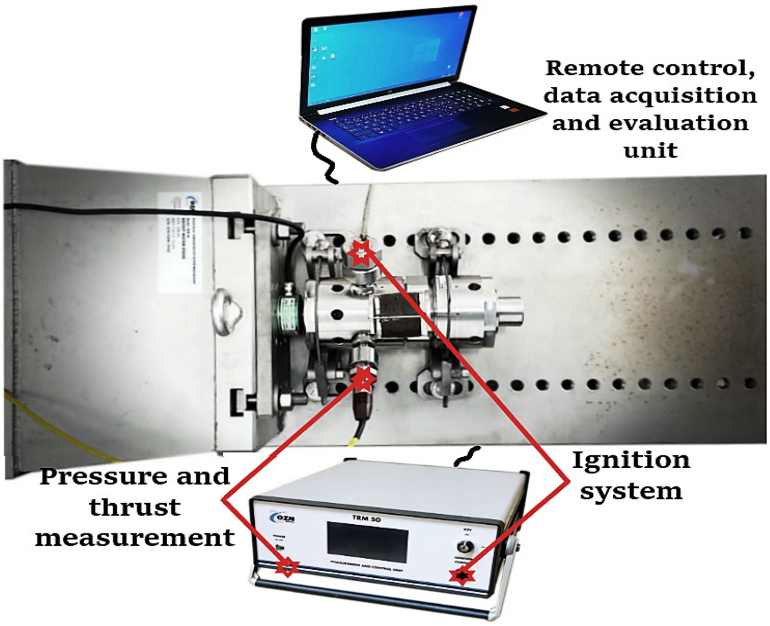


Figure S16. – Stand burner equipped with Subscale Rocket Motor TRM-35.

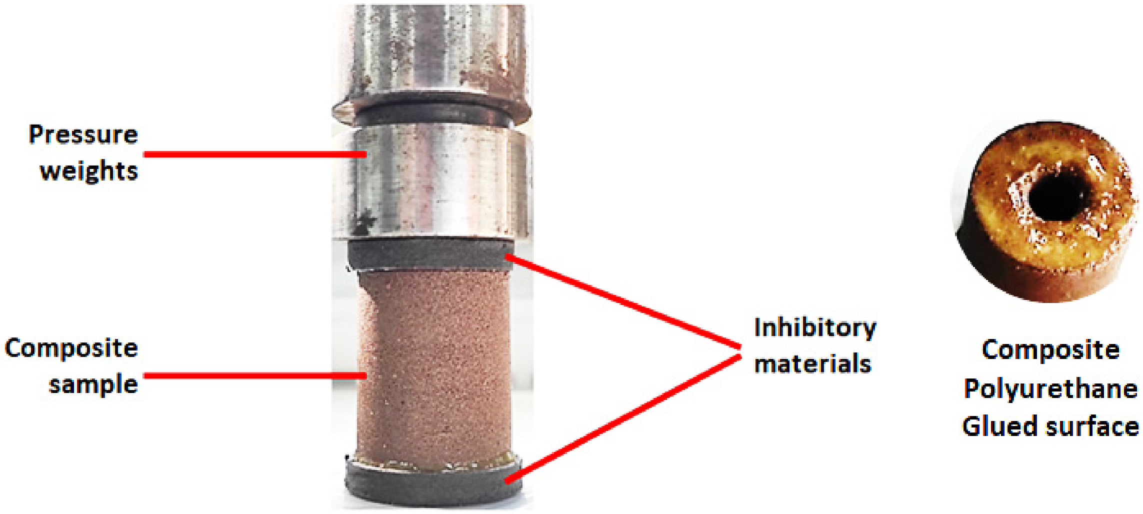
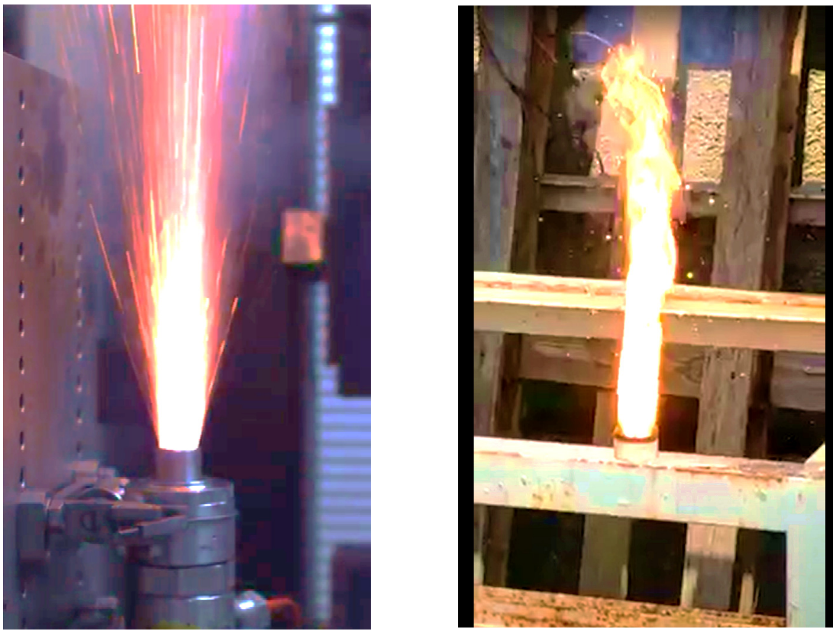


Figure S17. – Structural configuration of ECP_D5.

Figure S18. – Pyrotechnic composition for propellant ignition.



a. b.

Figure S19. – Flame configuration of ECP_D5 during the combustion (**a.** at nozzle exit; **b.** outdoor).

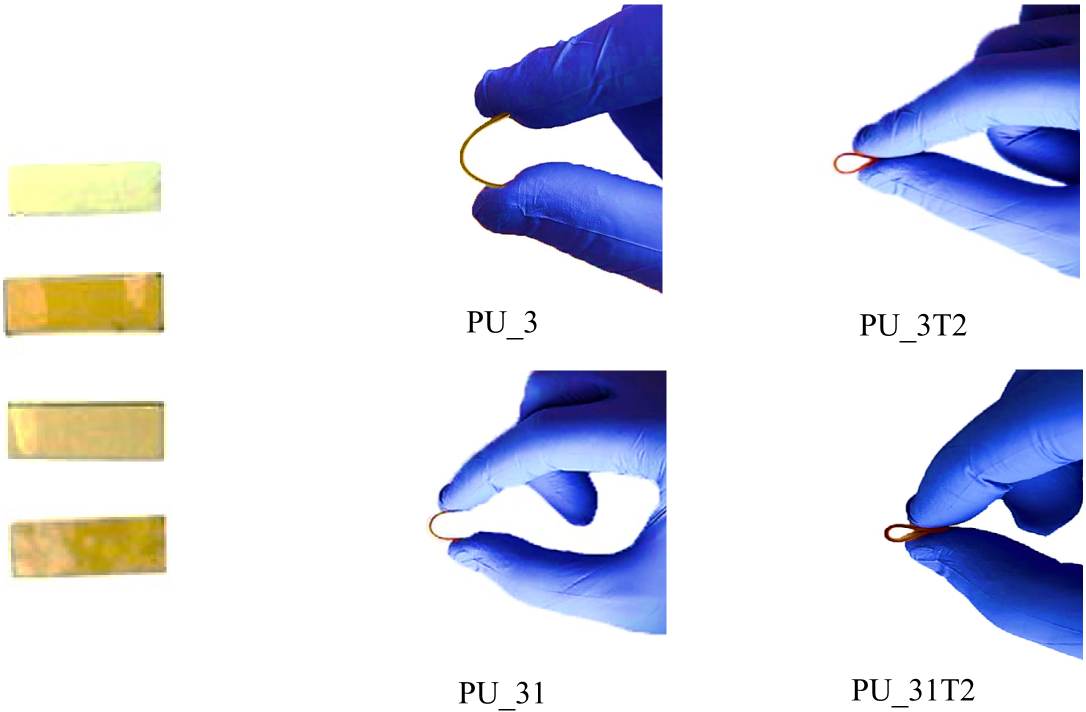


Figure S20. – Behavior of PUs during manual bending.

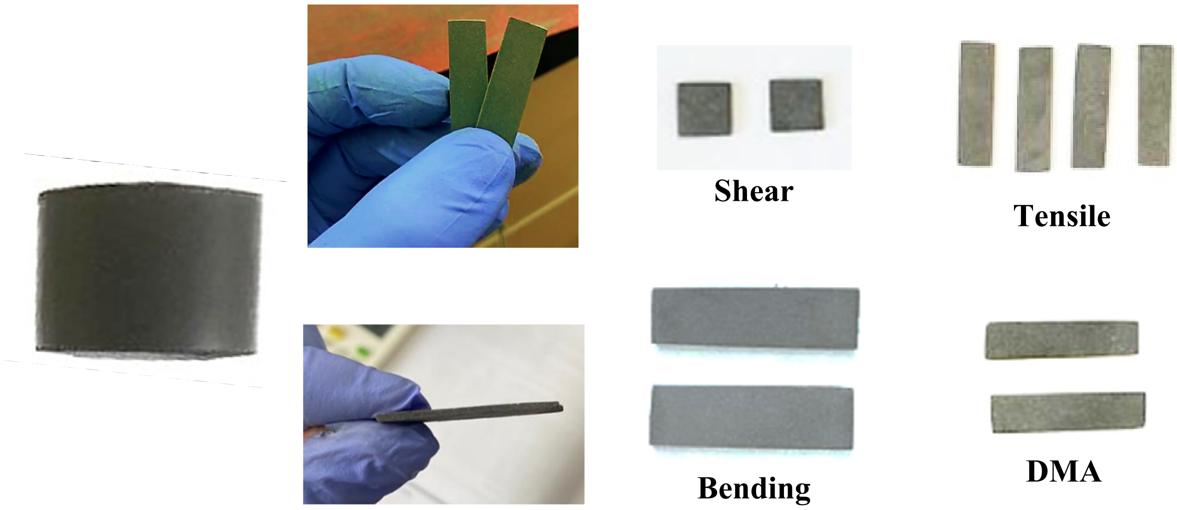


Figure S21. – Structural configurations of composite propellants for mechanical analysis.

Table S3. Thermal characteristics for polyurethane films, composite propellant formulations, and energetic plasticizer.

Sample	Evaluation results [°C]					
	Beginning temperature	Onset	Top	Max. Difference	End Temperature	Peak Type
PU_2	208.6	231.7	263.7	0.6	283.8	Exotherm
TEGDN	149.4	191.8	193.7	44.6	225.7	Exotherm
PU_2T1	161.5	179.2	200.8	3.9	228.7	Exotherm
PU_2T2	154.0	185.2	196.6	7.8	228.3	Exotherm
PU_21T1	148.3	182.3	199.4	6.2	200.2	Exotherm
PU_21T2	142.2	193.7	194.9	40.3	207.7	Exotherm
PU_3	208.8	239.5	278.7	0.7	289.7	Exotherm
PU_3T1	152.4	179.8	198.6	4.7	233.6	Exotherm
PU_3T2	143.1	185.6	196.2	14.4	227.9	Exotherm
PU_31T1	159.1	180.7	197.4	6.5	229.9	Exotherm
PU_31T2	150.9	190.3	191.2	52.4	202.5	Exotherm
ECP_A5	160.5	164.1	54.1	2.5	299.9	Exotherm
ECP_B5	155.8	165.3	183.7	32.8	195.8	Exotherm
ECP_D5	159.5	176.5	183.8	75.1	194.3	Exotherm

Table S4. Thermal properties of synthesized polyurethanes.

Sample	$T_{10\%}$[1] [°C]	T_{max1}[2] [°C]	T_{max2}[2] [°C]	T_{max3}[2] [°C]	T_{max4}[2] [°C]
PU_3	306.1	313.6	371.1	456.1	-
PU_31	313.5	313.5	410.9	-	-
PU_3T2	197.6	190.1	315.1	370.1	457.6
PU_31T2	181.4	193.9	326.4	408.9	-

[1]decomposition onset temperature (measured at 10 % weight loss).
[2]the maximum decomposition temperatures, corresponding to the maximum of DTG peaks.

Table S5. The decomposition process of the polyurethanes (weight loss versus temperature).

Sample	Weight loss [%]								
	200°C	**250°C**	**300°C**	**350°C**	**400°C**	**450°C**	**500°C**	**550°C**	**600°C**
PU_3	0.5	0.8	7.1	32.1	60.3	70.3	92.9	94.2	95.1
PU_31	1.1	1.4	6.4	19.4	43.4	77.4	85.9	87.8	88.6
PU_3T2	10.1	13.8	20.2	37.9	55.9	73.1	91.9	94.3	95.2
PU_31T2	18.4	25.1	29.5	39.7	58.8	81.7	87.5	88.9	89.7

Table S6. Heat of combustion, specific volume and T_g for our new composite propellants in comparison with the existing commercial formulations.

Sample	Qv [cal/g]	Vsp [l/kg]	T_g
HTPB composite propellant	1700	507	-72°C
Double based propellants	1020	798	-35.5°C
ECP_D5	1002	693	-32°C
ECP_B5	1010	658	-61°C