

Electronic Supplementary Information (ESI)

Graphene-Iron Oxide Nano Composite (GINC): An Efficient Catalyst for Ammonium Perchlorate (AP) Decomposition and Burn Rate Enhancer For AP based Composite Propellant

Abhijit Dey^{a*}, Javaid Athar^a, Pankaj Varma^a, Hima Prasant^a, Arun K.Sikder^{a*}, Santanu Chattopadhyay^{b*}

Received (in XXX, XXX) Xth XXXXXXXXX 20XX, Accepted Xth XXXXXXXXX 20XX

DOI: 10.1039/b000000x

Table S1: Comparison of important properties of graphene with CNT

Properties	Graphene	CNTs
Fracture Strength (GPa)	124 (Modulus: 1100GPa)	45
Density (g cm ⁻³)	>1	1.33
Thermal conductivity W/mK)	5000	3000
Electrical conductivity (S cm ⁻¹)	10 ⁶	5000
Charge mobility (cm ² V ⁻¹ s ⁻¹)	200000	100000
Specific surface area (m ⁻² g ⁻¹)	2630	400 (for nano tube paper)

Table S2. Thermal analysis results with different burn rate enhancer with AP

Sr. No	Composition	DSC @ 10°C/min					DTA @ 20°C/min			TGA@ 20°C/min	
		Peak temperature (°C)	ΔH (J/g)				initial temp. (T _{initial} , °C)	Max. temp. (T _{max} , °C)	Final temp (T _{max} , °C)	temperature (°C)	weight loss (%)
		Phase transition	1 st Peak	2 nd Peak	1 st Peak	2 nd Peak					
1.	AP	245.47	296.40	380.43	-583.1	-1849.34	241.46	299.70	374.36	239.37-401.48	75.09
2.	AP+1% Graphene	247.77	--	393.83	--	-3243.5	241.23	302.08	367.58	250.65-389.86	88.58
3.	AP+1%GINC	246.37	--	372.30	--	-4071.245	242.72	304.2	366.63	224.72-384.47	73.81
4.	AP+1% nano Fe ₂ O ₃	246.63	341.03	380.77	-1269.63	-627.908	242.02	302.49	366.92	234.17-389.67	96.54
5.	AP+1%Micronsize Fe ₂ O ₃	247.93	--	402.57	--	-2286.36	241.16	302.85	368.18	229.91-387.78	96.45

Table S3. Approximate propellant compositions

Sr. No	Ingredients	CP-1	CP-2	CP-3	CP-4
1.	Hydroxy terminated polybutadiene(HTPB)	10.4%	10.4%	10.4%	10.4%
2.	Dioctyl Adipate (DOA)	3.8%	3.8%	3.8%	3.8%
3.	Aduuuct:n-butane diol: Tri methylol propane (2:1)	0.12%	0.12%	0.12%	0.12%
4.	Toluene diisocuan (TDI)	0.68%	0.68%	0.68%	0.68%
6.	Ammonium perchlorate (AP)	68%	68%	68%	68%
7.	Aluminum (Al)	17%	17%	17%	17%
8.	Burn rate enhancer	0 part	1 wt.% over the batch (GINC)	1 wt.% over the batch (nano Fe ₂ O ₃)	1 part wt.% over the batch (Micron size Fe ₂ O ₃)

Table S4. Physico-chemical properties with different burn rate enhancer in propellant composition

Sr. No	Comp ⁿ	Theoretical performance parameters			Viscosity (Poise) Initial at 40°C	Density g/cc	Cal-Val (Cal/g)	Sensitivity parameter			Mechanical properties		
		C*, (m/s)	Flame Temperature (T _f , °C)	Specific Impulse (Isp,s)				Fric ⁿ	Impact % elong ⁿ	Ignition temp. (°C)	UTS, kgf/cm ²	% elongation	E-Modulus, kgf/cm ²
1.	CP-1	1584	1767	263.3	5440(44.3)	1.748	1882	144	46.5	282.59	10.5	43.7	44.6
2.	CP-2	1575	1727	261.7	5760(41.8)	1.755	1898	128	45.0	282.6	10.0	36.1	52.0
3.	CP-3	1573	1762	261.6	8340(43.1)	1.744	1880	128	42	282.5	8.10	65.8	22.8
4.	CP-4	1573	1762	261.6	6450(45.4)	1.753	1878	128	44	282.5	7.45	53.5	25.77

CP-1: Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(Fe₂O₃)- Nil, **CP-2:** Binder (15%)+Al(17%)+AP(68%)+ Burn rate enhancer(GINC)- 1wt.% over the batch, **CP-3:** Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(nano Fe₂O₃)- 1 wt. % over the batch, **CP-4:** Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(Micron size Fe₂O₃)- 1 wt. % over the batch

Table S5. Thermal analysis results with different burn rate enhancer in propellant composition

Sr. No	Comp ⁿ	Peak temp. (°C) @ 10°C/m in	DSC	DTA @ 20°C/min			TGA@ 20°C/min		Thermophysical properties				
			ΔH (J/g)	Act. Energy (KJ/M)	initial temp. (T initial, °C)	Max. temp. (Tmax, °C)	Final temp (Tmax, °C)	Temp. (°C)	weight loss (%)	Thermal Expansion coefficient (×10 ⁻⁶ /C) at 30°C	Thermal Diffusivity cm ² /sec	Specific heat, J/kg-K	Thermal conduct. W/mk
1.	CP-1	400.7	-1671.4	279.7	242.9	300.33	371.0	249.4-416.1	62.9	88.11	0.0027	1196.5	0.57
											0.0028	1197.9	0.58
2.	CP-2	356.23	-1664.7	218.9	242.3	307.9	357.75	230.39-390.61	61.06	86.2	0.0026	1210.0	0.59
											0.0026	1212.2	0.58
3.	CP-3	366.9	-1620.9	109.5	242.9	307.78	355.98	249.4-410.7	74.98	81.4	0.0026	1307.4	0.61
											0.0027	1354.4	0.63
4.	CP-4	366.2	-1623.1	234.3	242.9	300.33	371.0	249.4-416.1	62.9	84.4	0.0026	1214.0	0.60
											0.0027	1215.2	0.58

CP-1: Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(Fe₂O₃)- Nil, **CP-2:** Binder (15%)+Al(17%)+AP(68%)+ Burn rate enhancer(GINC)- 1wt.% over the batch, **CP-3:** Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(nano Fe₂O₃)- 1 wt. % over the batch, **CP-4:** Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(Micron size Fe₂O₃)- 1 wt. % over the batch

Table S6. Physico-chemical properties with different burn rate enhancer in propellant composition

Sr. No	Comp ⁿ	Ballistic properties				
		Burn rate (mm/s)			n value, 5-10 Mpa	a value 5-10Mpa
		5 Mpa	7 Mpa	10 Mpa		
1.	CP-1	6.68	7.91	9.47	0.5	0.931
2.	CP-2	9.91	12.02	13.32	0.425	1.91
3.	CP-3	9.27	10.82	12.49	0.43	1.73
4.	CP-4	8.825	10.285	11.92	0.43	1.622

CP-1: Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(Fe₂O₃)- Nil, **CP-2:** Binder (15%)+Al(17%)+AP(68%)+ Burn rate enhancer(GINC)- 1wt.% over the batch, **CP-3:** Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(nano Fe₂O₃)- 1 wt. % over the batch, **CP-4:** Binder (15%)+Al(17%)+AP(68%)+Burn rate enhancer(Micron size Fe₂O₃)- 1 wt. % over the batch