

# Peter Golding



# ENHANCED ENERGETIC POLYPHOSPHAZENES

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# PLASTIC BONDED EXPLOSIVES (PBXs)

Crystalline Filler + Polymeric Binder + Additives

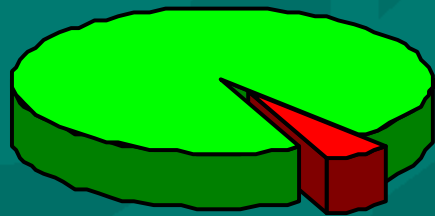
Filler Provides Energy

Binder Provides Shape/Robustness

& Desensitises Most Explosives

Traditional Inert Binder

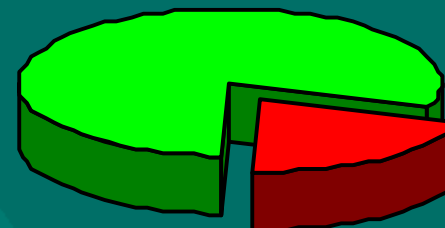
*filler*  
(95%)



*binder*  
(5%)

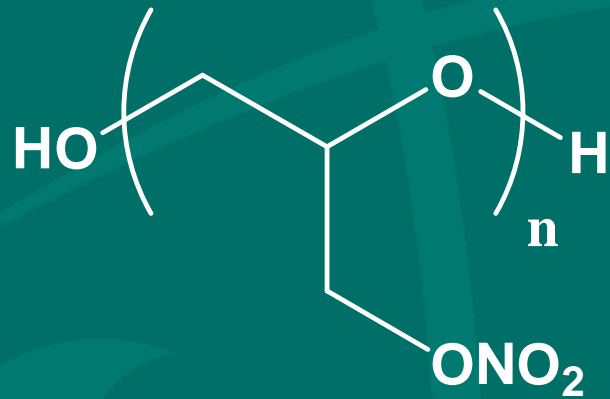
Energetic Binder

*filler*  
(80%)

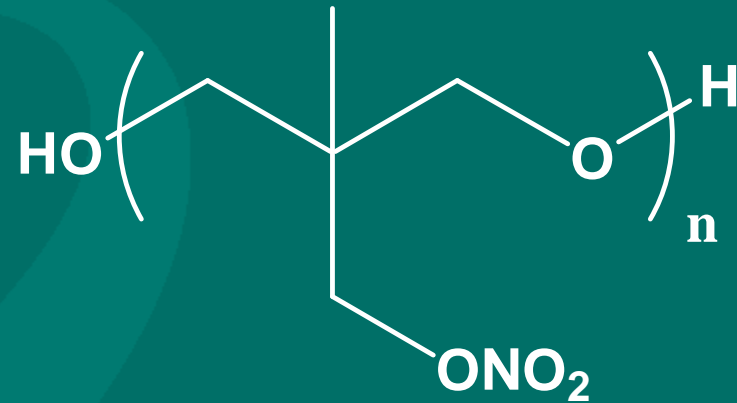


*binder*  
(20%)

# CARBON BASED ENERGETIC POLYMERS

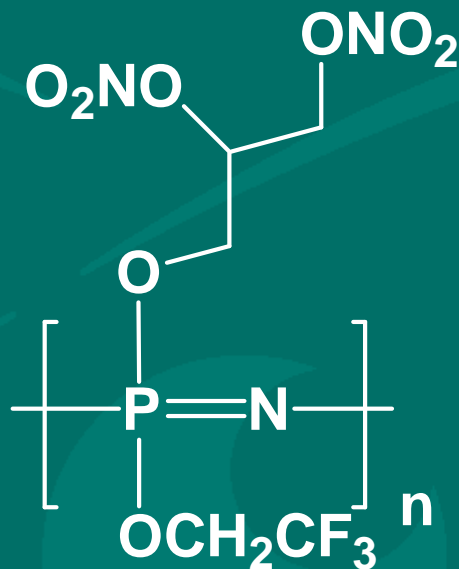


**PolyGLYN**

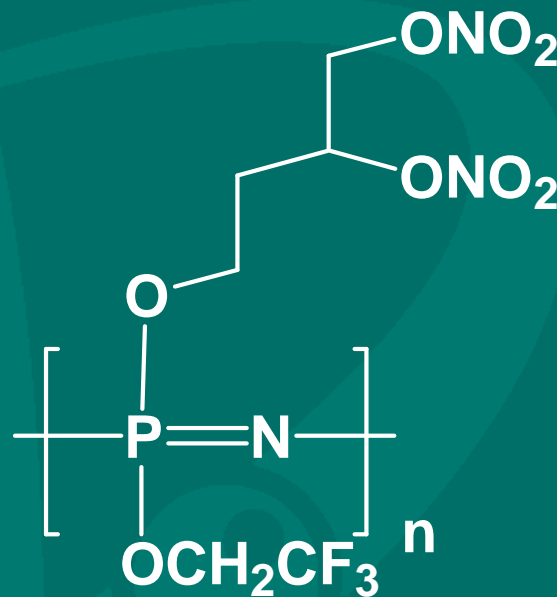


**PolyNIMMO**

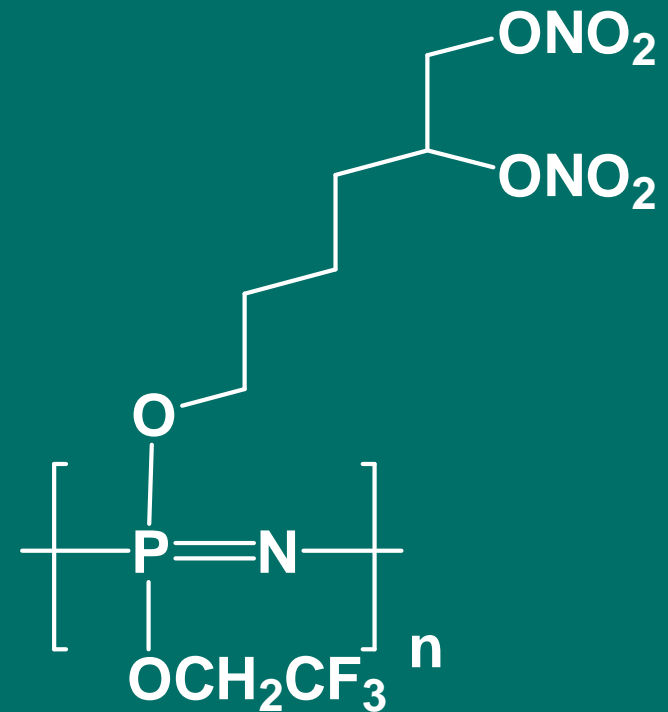
# NITRATE ESTER FUNCTIONALISED POLYPHOSHAZENES PREVIOUSLY SYNTHESISED AT AWE



C3 PPZ

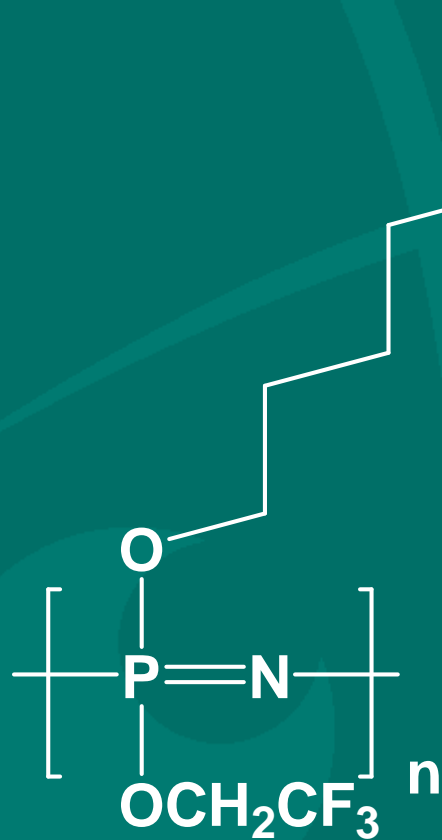


C4 PPZ

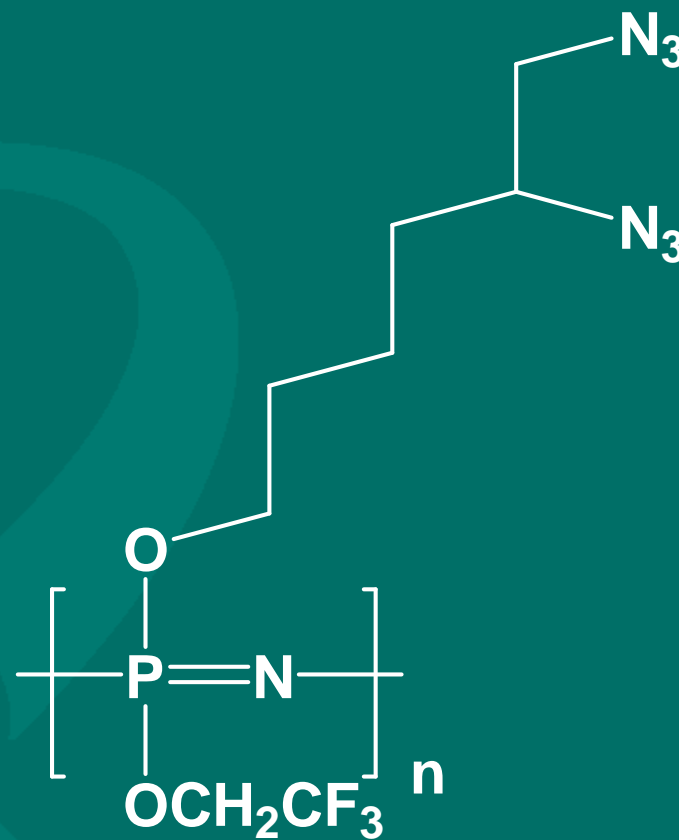


C6 PPZ

# AZIDE FUNCTIONALISED POLYPHOSPHAZENES PREVIOUSLY SYNTHESISED AT AWE



**C6 Mono-N<sub>3</sub> PPZ**

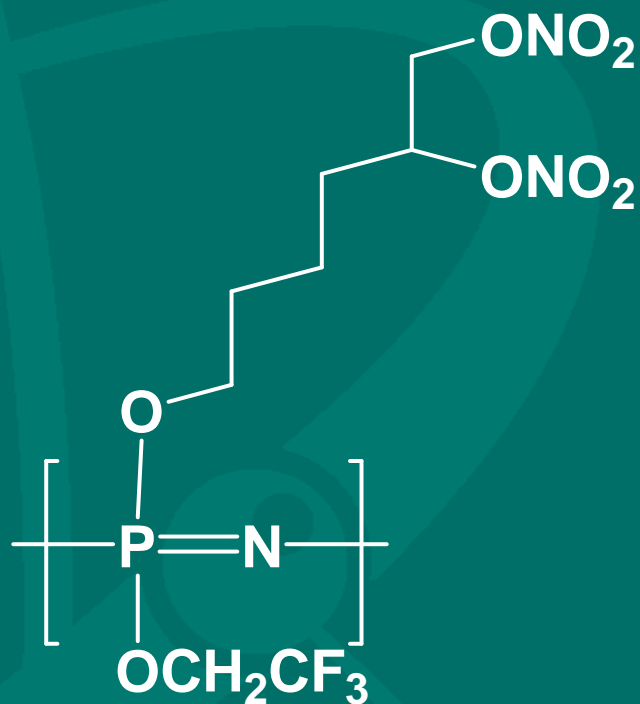


**C6 Di-N<sub>3</sub> PPZ**

# POLYPHOSPHAZENE TOPICS

- Mixed binder systems:-
  - i) polyphosphazene/polyNIMMO
  - ii) polyphosphazene/polyGLYN
- Synthesis of polyphosphazene homopolymers  
(ie full energetic substitution)
- Formulation with common high explosives

# 70% - C6 DINITRATE ESTER FUNCTIONALISED MIXED SUBSTITUENT POLYPHOSHAZENE



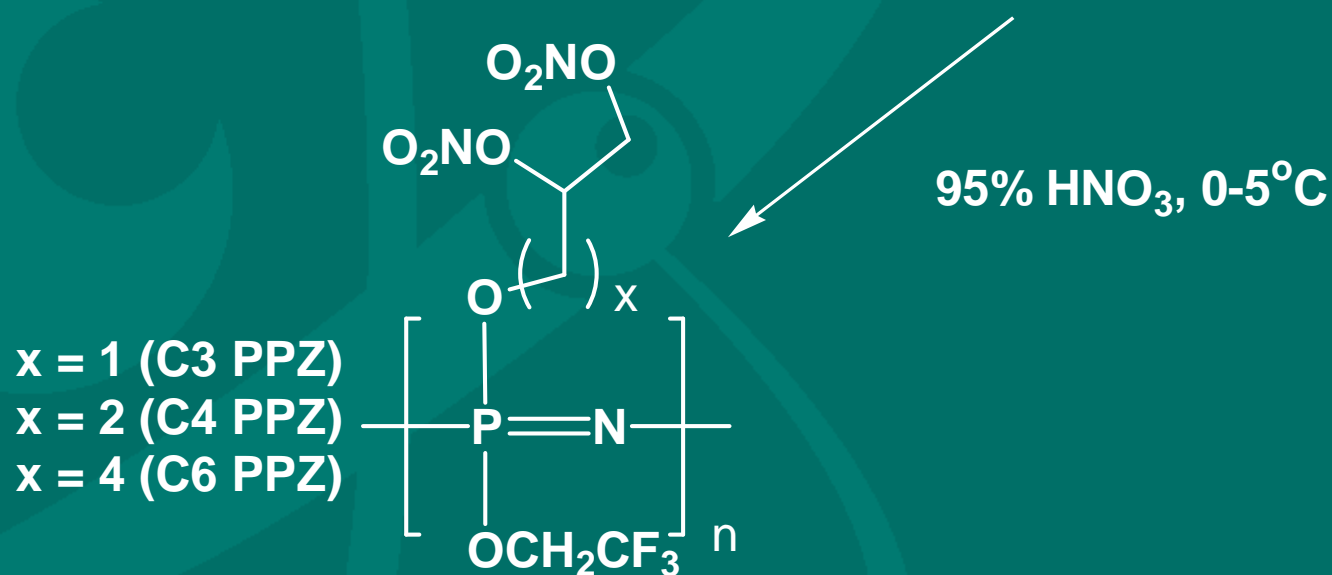
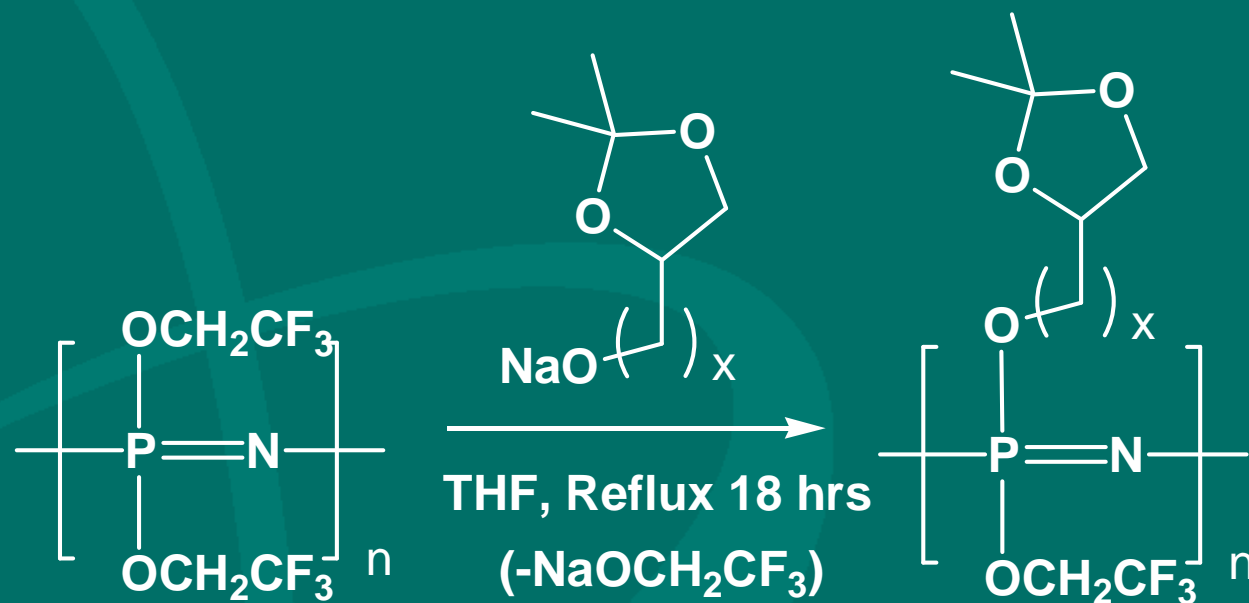
# PolyGLYN/PolyPHOSHAZENE DATA

Weight fraction of PolyGLYN	Weight fraction of 3	T <sub>g</sub> (°C) (Uncured)	Energy density (J/cm <sup>3</sup> )*
100	0	-31.1	2900
75	25	-32.4	3117
60	40	-32.7	3247
50	50	-37.3	3334
40	60	-40.3	3421
25	75	-43.3	3551
0	100	-45.8	3768

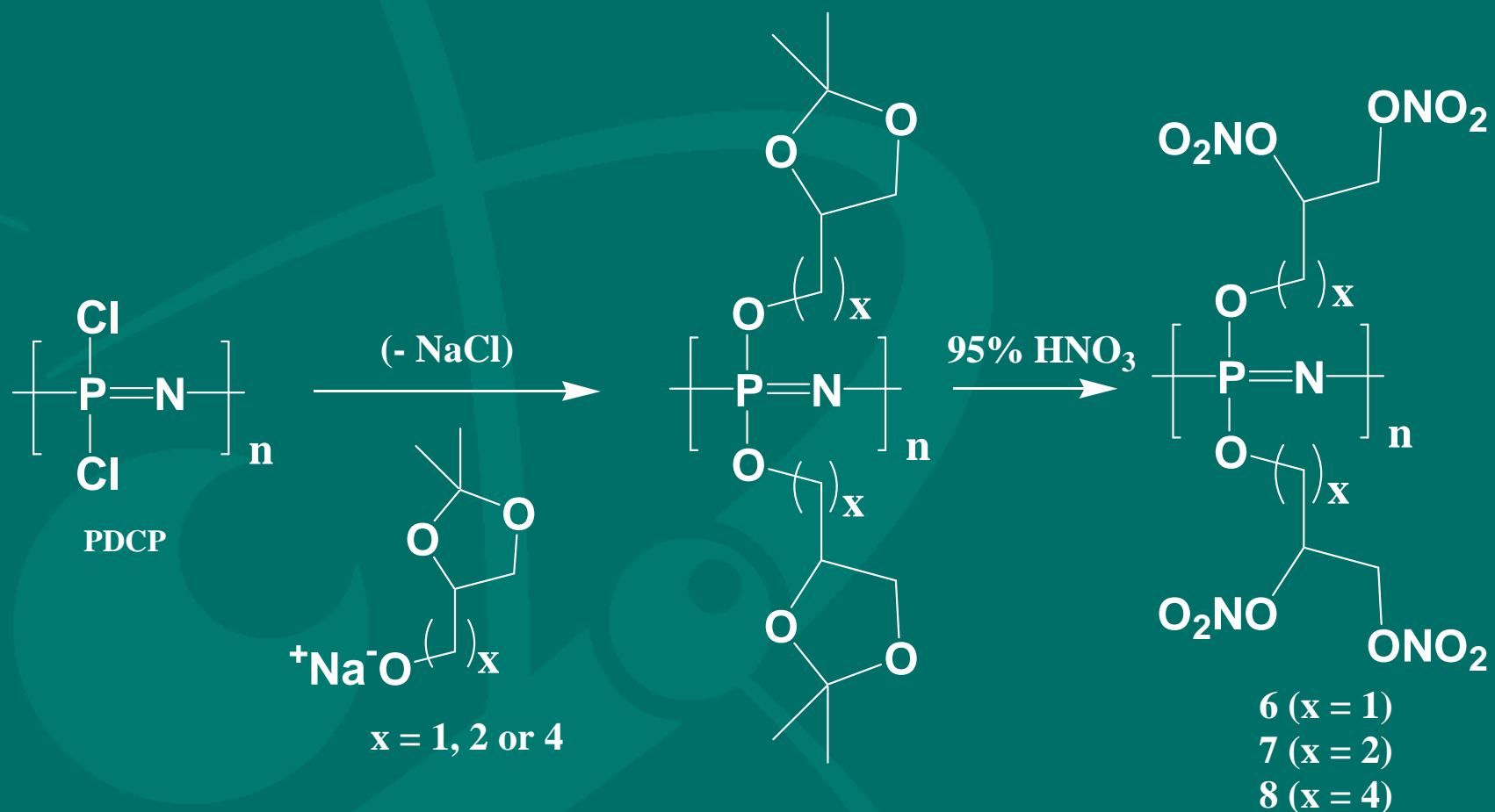
# PolyNIMMO/PolyPHOSPHAZENE DATA

Weight fraction of PolyNIMMO	Weight fraction of 3	T <sub>g</sub> (°C) (Uncured)	Energy density (J/cm <sup>3</sup> )*
100	0	-32.8	1638
80	20	-28.7, -43.4	2064
60	40	-29.6, -44.3	2490
40	60	-30.4, -46.0	2916
0	100	-45.8	3768

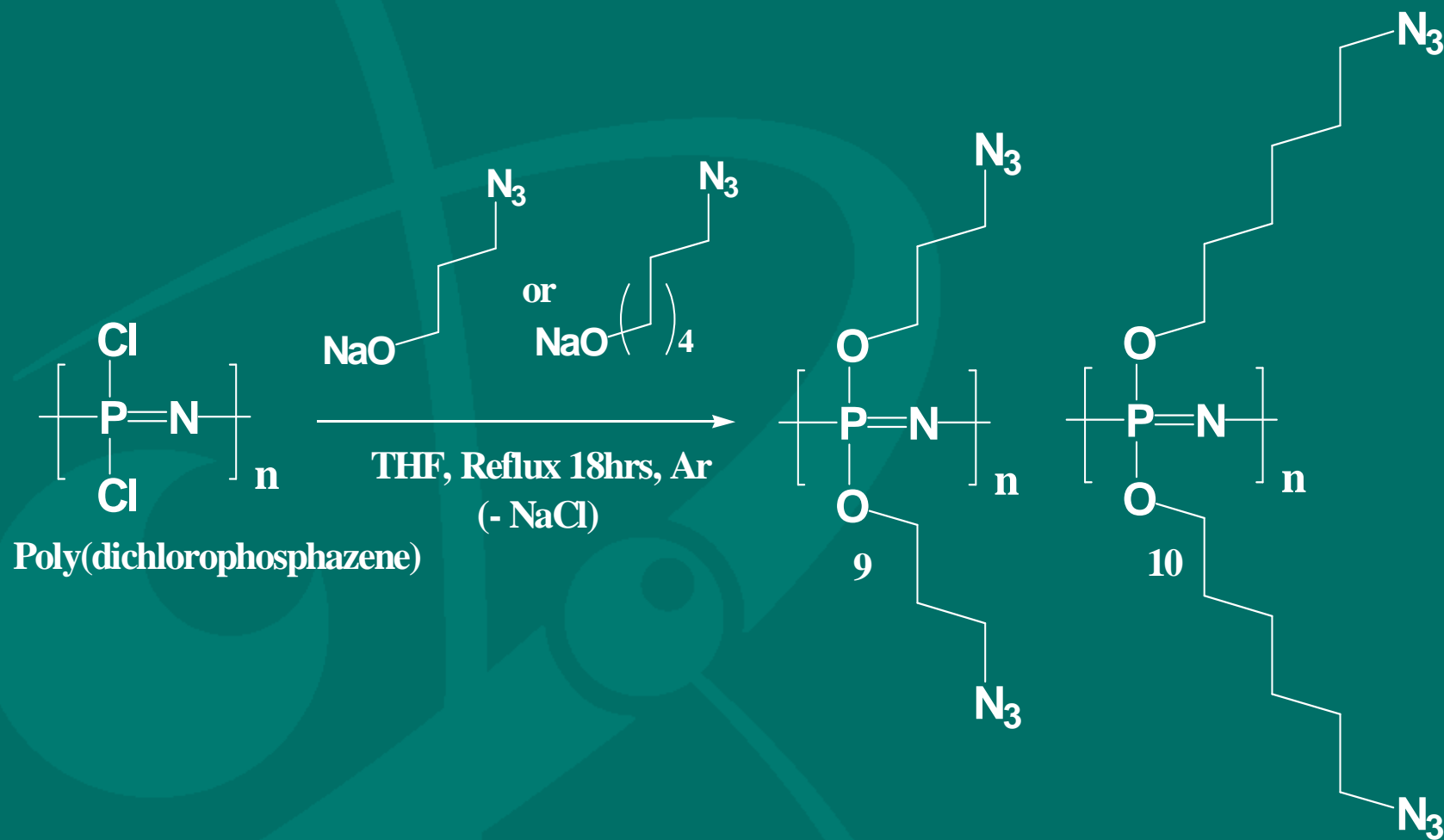
# SYNTHESIS OF NITRATE ESTER FUNCTIONALISED MIXED SUBSTITUENT POLYPHOSHAZENES



# SYNTHESIS OF NITRATE ESTER FUNCTIONALISED HOMOPOLYPHOSHAZENES



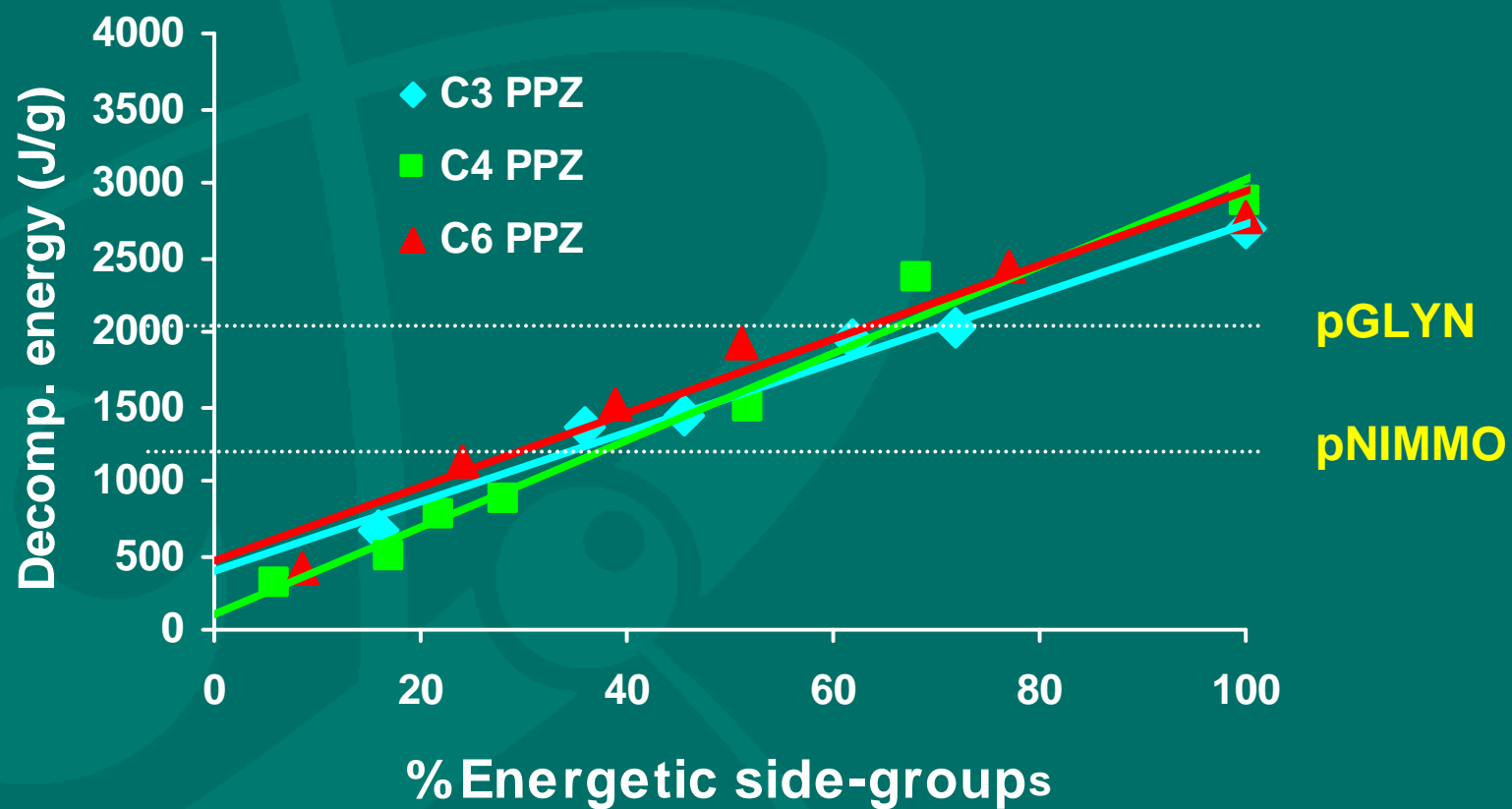
# SYNTHESIS OF AZIDO FUNCTIONALISED HOMOPOLYPHOSHAZENES



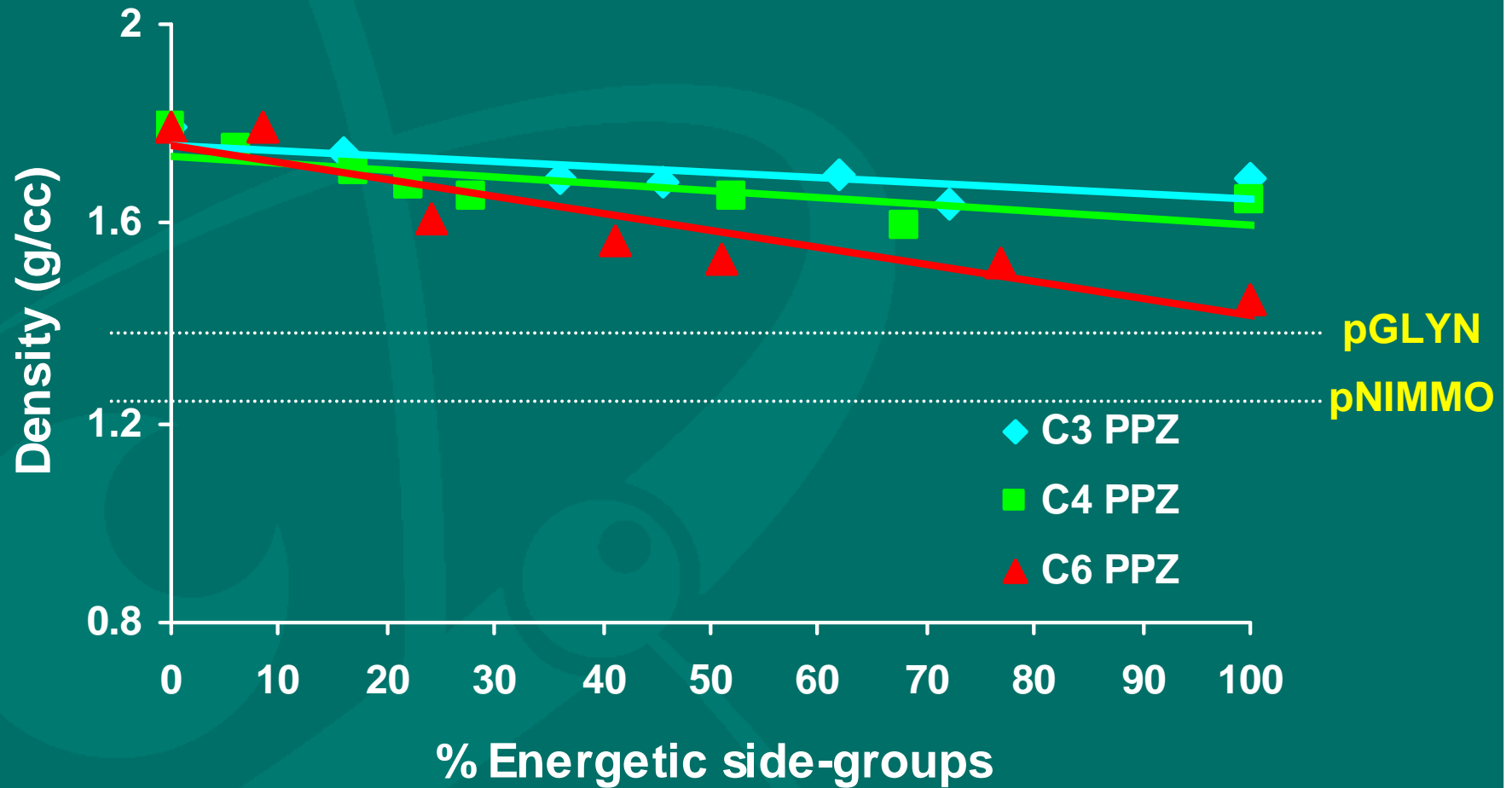
# POLYPHOSPHAZENE PROPERTIES

Polymer	Decomposition Energy (DSC) (J g <sup>-1</sup> )	Density (g cm <sup>-3</sup> )	Energy Density (J cm <sup>-3</sup> ) [% higher than PolyGLYN]	Glass Transition Temperature (°C)
6 C3,ONO2	2690	1.69	4550 [57]	-32.5
7 C4,ONO2	2880	1.65	4750 [63]	-23.8
8 C6,ONO2	2760	1.45	4002 [38]	-35.2
9 C3,N3	1825	1.35	2465	-73
10 C6, N3	1665	1.16	1930	-99
Mixed Substituent Polyphosphazenes	2020 – 2430	1.52 – 1.65	3333 – 3792	-13 to -55
PolyNIMMO	1300	1.26	1638	-33.0
PolyGLYN	2000	1.45	2900	-30.0

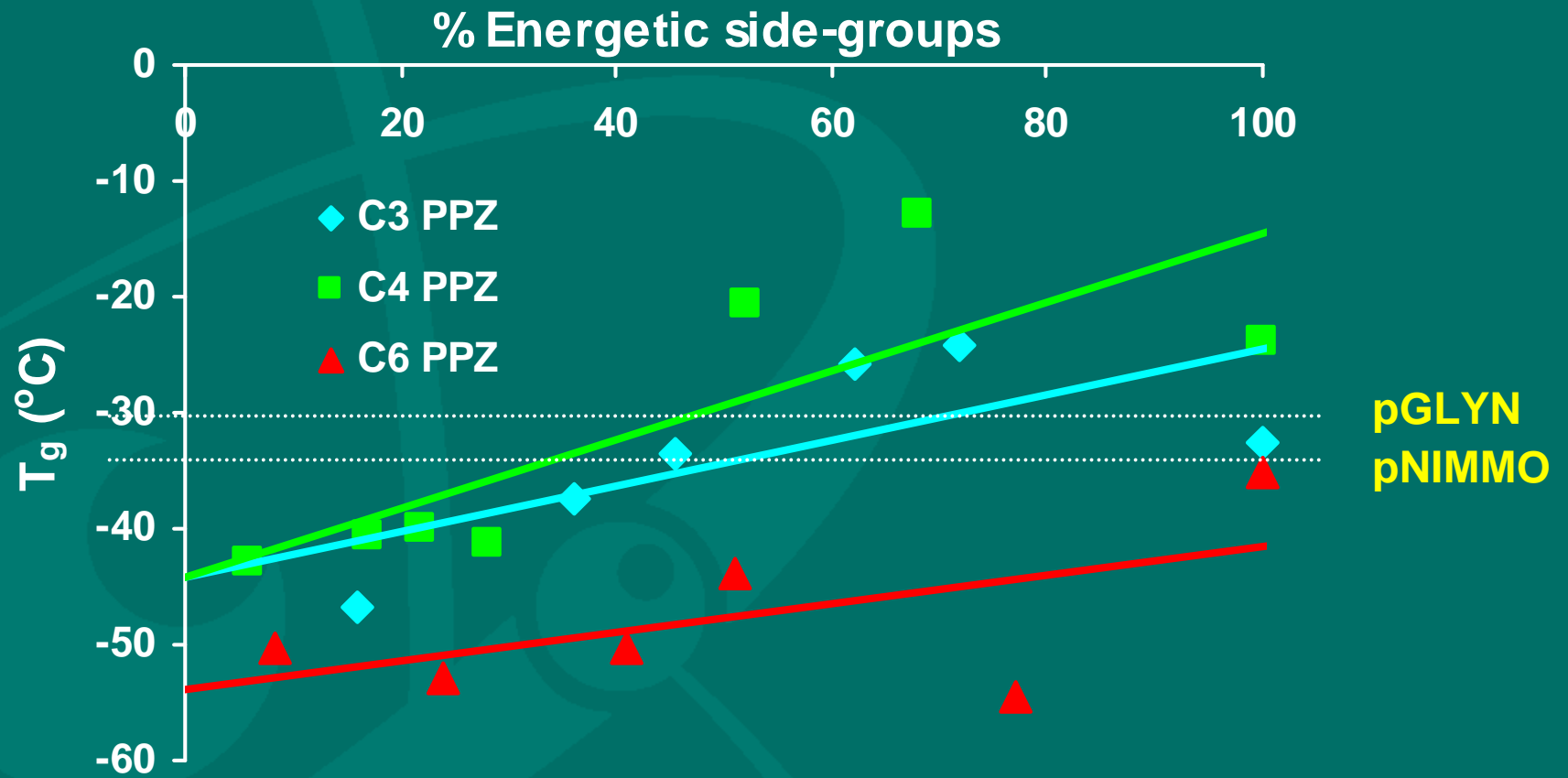
# DECOMPOSITION ENERGIES OF NITRATE ESTER FUNCTIONALISED POLYPHOSPHAZENES



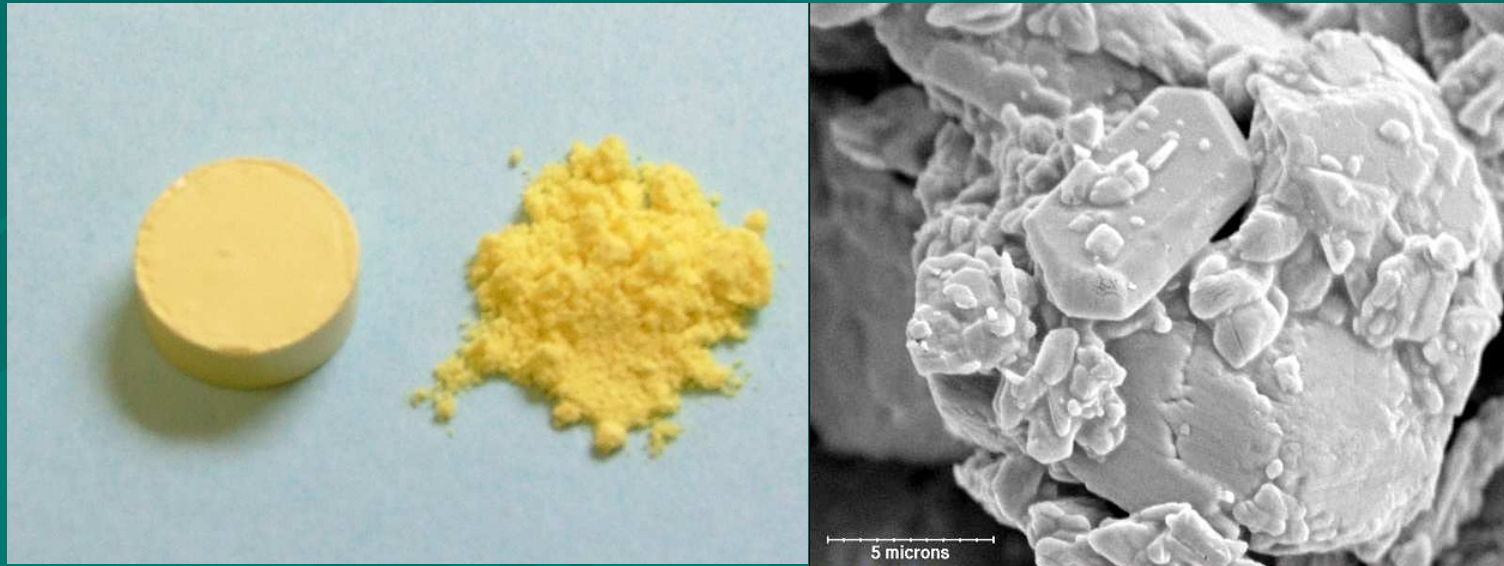
# DENSITY VALUES OF NITRATE ESTER FUNCTIONALISED POLYPHOSPHAZENES



# GLASS TRANSITION TEMPERATURES OF NITRATE ESTER FUNCTIONALISED POLYPHOSPHAZENES



# POLYPHOSPHAZENE FORMULATIONS



TATB/3 (70% Nitrate Ester), 95:5 weight percent

# POLYPHOSPHAZENE FORMULATIONS



**HMX/3 (70% Nitrate Ester), 95:5 weight percent**

# POLYPHOSPHAZENE FORMULATIONS



FOX-7/4 (60% Azide), 90:10 weight percent  
(showing damage due to mould adhesion)

# POLYPHOSPHAZENE FORMULATIONS

Polyphosphazene	HE	% Binder	% ES
Nitrate ester C6	HMX	5,10	17,70
Nitrate ester C3	HMX	10	18,68
Azide C6	HMX	10	60 <b>Compatibility?</b>
Nitrate ester C6	TATB	5,10	17,70
Nitrate ester C3	TATB	5,10	18,68
Azide C6	TATB	5,10	60

# POLYPHOSPHAZENE FORMULATIONS

Polyphosphazene	HE	% Binder	% ES
Nitrate ester C6	HNS	1,5,10*	17,70*
Nitrate ester C3	HNS	1,5	68
Azide C6	HNS	5	60
Nitrate ester C6	FOX-7	5,10	70
Azide C6	FOX-7	10	60
			* Low F of I

# CONCLUSIONS

- Potential mixed binder systems demonstrated
  - i) polyphosphazene/polyNIMMO
  - ii) polyphosphazene/polyGLYN
- Product set expanded to include:-
  - Highest measured energy-density
  - Lowest glass transition temperature
- Highly substituted azide products prepared (now tractable)
- Good binder properties with HMX, TATB, FOX-7 and HNS formulations