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Author(s)	Lee, Priscilla Li Yi
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School of Materials Science and Engineering

Student: Lee Li Yi Priscilla

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Spray-drying Processing and Characterization of Sodium Nitrite-Aluminium

Introduction

Spray drying is adopted for the processing of sodium-nitrite-aluminium to investigate how the process of spray drying forms a structure of fuel and oxidizer via the establishment of microencapsulation. This was proposed to improve the interfacial contact between them for good combustion kinetics and thermal properties. Sodium nitrite serves as an oxidizer by releasing oxygen upon thermal decomposition. Aluminium will act as a fuel, which has been extensively used due to its high enthalpy of heat of 31kJ/g.[1] Two sizes of Aluminium were used to explore how they affect the particle formation and thereby the thermal and kinetic properties.

$2NaNO_2 \rightarrow Na_2O + N_2 + 3/2O_2$ (experimentally after 660°C)

Equation 1 Thermal Decomposition of Sodium Nitrite [2]

$4Al + 3O_2 \rightarrow 2Al_2O_3$

Equation 2 Oxidation of Aluminium

Experimental (Spray drying process)

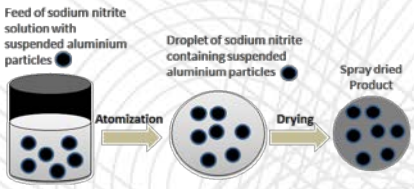


Table 1 Table of optimized process parameters

Feed Concentration (%w/v)	(Solvent) Ethanol: Water ratio	Pump speed (ml/min)	Spray air flow rate (l/hr)	Aspirator rate (%)	Inlet Tempt. (°C)
1	70:30	3.5	600	100	80

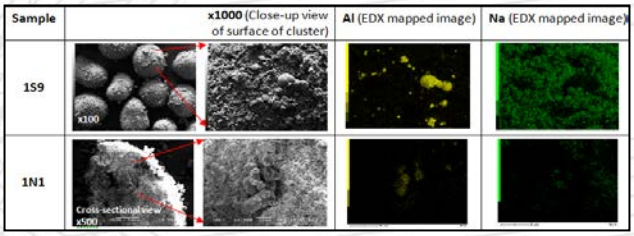


Figure 1 Structural characterization of spherical clusters by SEM-EDX

Discussion and Results

Studies include structural, thermal and kinetic characteristics of the spray dried products by SEM-EDX, DSC-TGA and parr dynamic measurement (which measures the rate of change in pressure - dP/dt) respectively.

Major Achievements

Structural characteristics

- Achieved filled spherical clusters with high density (<10% difference to theoretical density)
- Achieved relatively homogenous particle size distribution of 100 to 400 µm
- Spray drying has allowed the control of particle size by controlling the process parameters, i.e. feed concentration

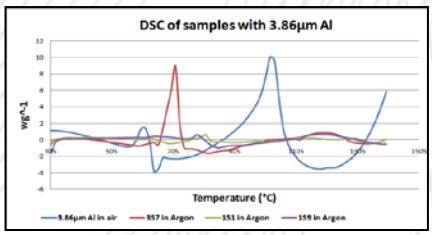
Thermal and Kinetic characteristics

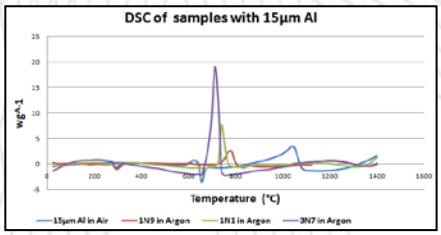
- Compared to heating Al alone in air, heating spray dried Al/$NaNO_2$ in argon showed early exothermic temperature which is postulated to be due to the close interfacial contact of the oxidizer and fuel
- Better combustion kinetics are obtained with smaller-sized and spherical Al, and with higher amount of Al in the composition for combustion in air

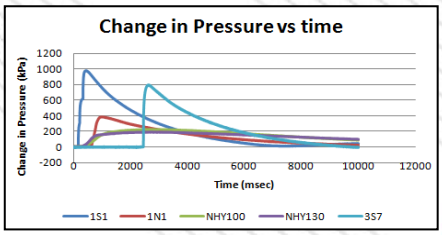
Table 2 Summary table of structural, combustion and kinetic characteristics

Sample		Feed Composition (wt%) Al : $NaNO_2$	Measured Composition [a] (wt%) Al : $NaNO_2$	Structural Characteristics: Particle Size (µm)	Structural Characteristics: Measured Density (g/cm3) by helium pycnometer	Structural Characteristics: Morphology	Combustion Kinetics: dP/dt (kPa/msec) measured in Air	Thermal Analysis: Exothermic Peak (DSC Tempt. °C) measured in Argon	Thermal Analysis: Expt. ΔH combustion (kJ/g) measured in Air
Samples using NHY130	1S1	50:50	47.1: 52.9	217 – 391[b]	2.51	Near-Spherical clusters	61.1	800	14.2
	3S7	30:70	25.8: 74.2	174 – 434[b]	2.33		26.7	700	6.8
	1S9	10:90	3.8: 96.2	196 – 326[b]	2.15		–	780	DNI
Samples using NHY100	1N1	50:50	60.3: 39.7	217 – 391[b]	2.63		3.58	750	16.2
	3N7	30:70	26.7: 73.3	217 – 325[b]	2.22		DNI	720	6.8
	1N9	10:90	8.6: 91.4	109 – 217[b]	2.05		–	790	DNI
								Exothermic Peak (DSC Tempt. °C) measured in Air	
Aluminium	NHY130	100:0	-	3.68[c]	2.71	Spherical particles	0.559	1019	26.9
	NHY100	100:0	-	15.41[c]	2.77	Granules	0.37	1033	29.9

DNI: Did not ignite
[a] Measured composition by first obtaining XRD spectra, followed by TOPAS software analysis
[b] Estimated visually from SEM micrographs
[c] D-50 of particles obtained from supplier

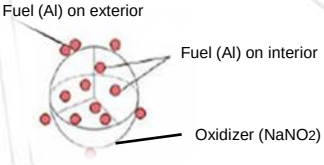






Conclusion

Established a microstructure of spray dried spherical cluster (of oxidizer enveloping the fuel) with good combustion kinetics and thermal properties, for high packing density required for post-processing applications



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1. David Lide, CRC Handbook of Chemistry and Physics, 88th Edition
2. Kurt H. Stern, "High Temperature Properties and Thermal Decomposition of Inorganic Salts with Oxyanions", CRC Press 2001

Project Title: Processing and Characterization of Oxidizer-coated Powders via Spray Drying

Supervisor: A/P Alfred Tok ling Yoong **Co-supervisor: Dr Lee Yiew Wang**