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Evaluation of the Effect of Surface Area on DNAN Based Explosives

NDIA Insensitive Munitions & Energetic Materials Technology Symposium 2013

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Topics of Discussion

- DNAN Based Explosives
- Surface Area Measurements
- Analytical Analysis
- Brookfield Viscosity
- Pressing Study
- Shock Sensitivity (LSGT)
- Conclusions and Future Work

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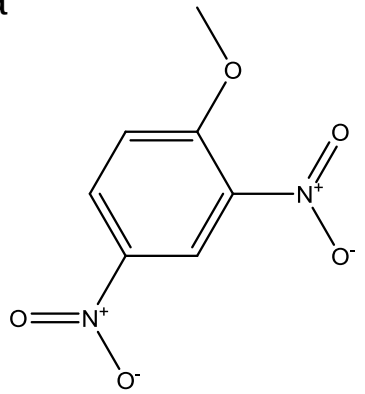
DNAN Based Explosives

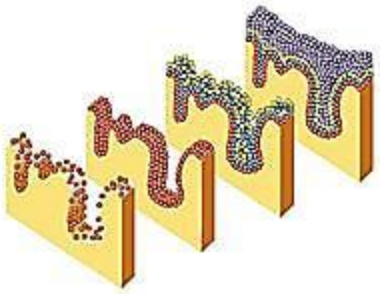
- 2,4-dinitroanisole (DNAN)
  - Melt ingredient used in insensitive formulations such as IMX-101 and IMX-104
  - Melting Point of 95°C
- Traditional Melt Pour Manufacturing Process
  - Limited by viscosity of mixture
  - Limits amount of high surface area ingredients in formulation
    - Evidence that sensitivity is decreased with higher surface area
- Surface Area Study
  - New process not limited by viscosity
  - High and low surface area values
    - Varied by ratio of coarse and fine ingredients

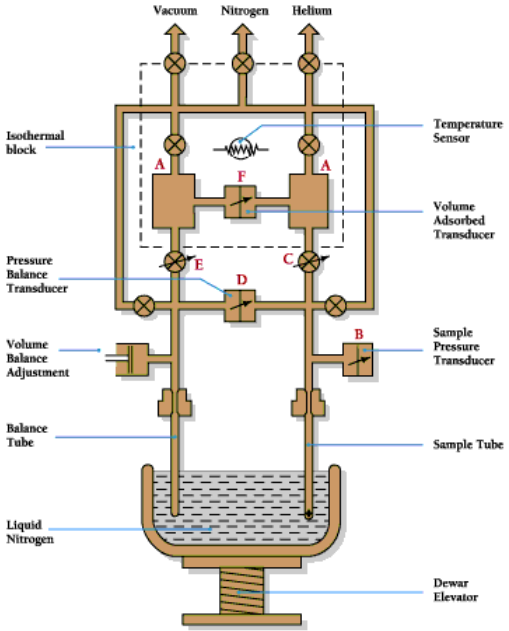


2,4-dinitroanisole
(DNAN)

Surface Area Measurements – BET

- Brunauer-Emmett-Teller (BET) Theory
  - Extension of Langmuir theory
  - Explains the physical adsorption of gas molecules on a solid surface
  - Gas molecules physically adsorb on a solid
- Gemini VII 2390a – Surface Area Analyzer
  - Manufactured by Micromeritics
  - Twin tube system which allows for accurate measurements of even low surface area materials
  - Uses BET theory to determine surface area value





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Surface Area Measurements - Results

Sample ID	1114-18	1114-20	1114-22	1114-24	1114-26	1114-28	1114-30	1114-32	1114-34	1114-36	1114-38
BET SA (m^2/g)	1.5645	1.3962	1.2909	1.2761	1.0128	0.9151	0.8229	0.7850	0.5528	0.4781	0.3941
	High Surface Area										Low Surface Area

- Each sample was run in duplicate
  - Duplicate results were all plotted on same BET Transform plot and used to calculate SA
- Five pressure points used to generate linear section of BET Transform Plot
- Able to see difference in BET SA even with small changes in ingredient ratios

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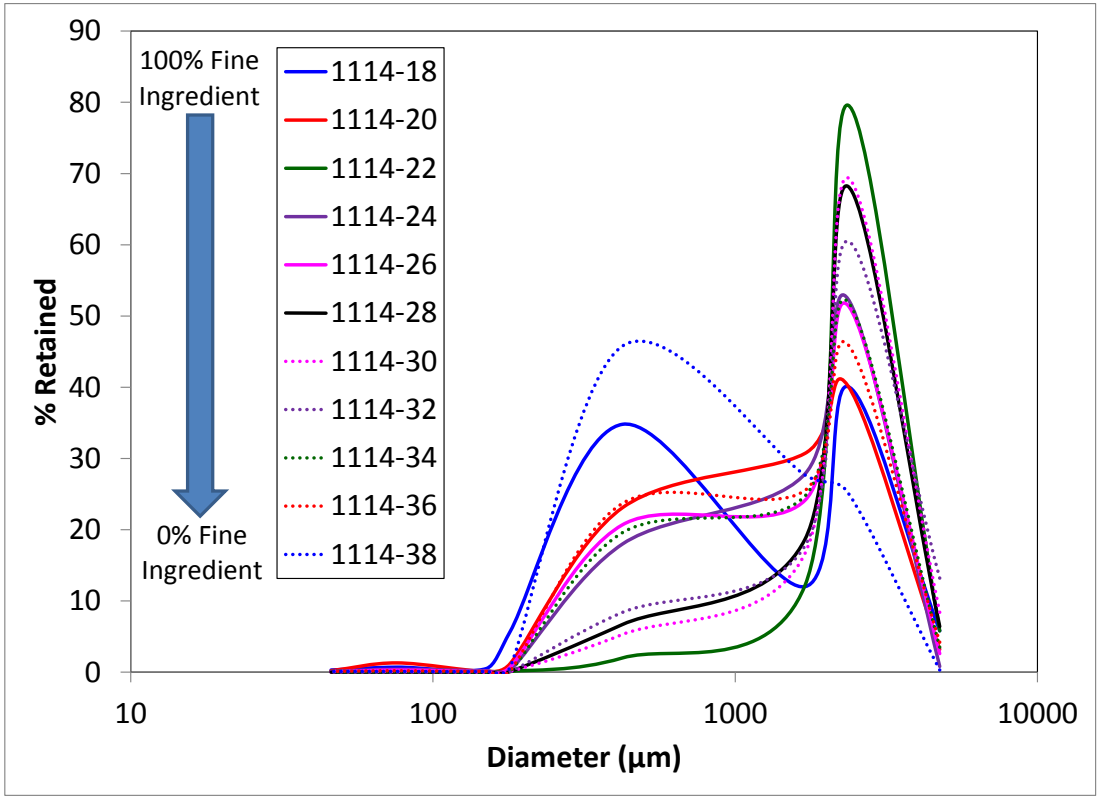
Analytical Analysis – Characterization Data

Batch ID		1114-18	1114-20	1114-22	1114-24	1114-26	1114-28	1114-30	1114-32	1114-34	1114-36	1114-38
Yield (%)		91.33	84.25	99.40	95.58	93.28	100.29	99.80	100.09	92.69	98.45	83.91
Composition												
Melting Point (ºC)		89.93	90.12	90.58	89.81	90.02	90.32	90.36	90.79	90.06	90.17	90.38
Exothermic Onset (ºC)		205	212	207	216	215	208	207	206	200	201	209
Bulk Density (g/cc)		1.04	1.06	1.02	1.03	0.96	0.96	0.95	0.96	0.96	0.99	1.00
Impact (cm)		195.7	>200	>200	>200	>200	>200	155.5	>200	>200	>200	>200
Impact Standard (cm)		17.84	17.84	22.91	22.91	22.91	22.91	15.55	15.55	29.85	29.85	29.85
Friction (N)		204.0	175.7	210.4	217.2	216.0	218.4	277.7	244.4	205.6	214.3	210.6
Friction Standard (N)		129.1	129.1	180.9	180.9	180.9	180.9	164.5	164.5	145.8	145.8	145.8
Flowdex		20	14	18	16	18	18	26	24	18	20	14
Moisture (%)		0.026	0.019	0.026	0.030	0.033	0.044	0.032	0.039	0.047	0.035	0.040
VTS (ml/g)		0.14	0.11	0.21	0.11	0.17	0.13	0.11	0.08	1.25	0.08	0.08
Screens (% Pass)	4	94.2	96.8	94.2	99.2	97.4	93.6	91.6	86.8	96.5	95.8	99.7
	8	54.1	56.5	14.6	46.8	45.9	25.4	22.2	26.3	44.5	49.8	74.5
	12	42.1	25.9	2.5	19	21.8	6.8	5.6	8.6	19.8	24.3	46.8
	40	7.3	2.8	0.5	1	1.1	0.1	0.3	0.2	0.2	0.6	1
	80	1.6	1.6	0.4	0.7	0.4	0	0.1	0.1	0.1	0.4	0.3
	100	1.1	1.5	0.3	0.5	0.3	0	0	0	0.1	0.3	0.1
	200	0.4	0.2	0.1	0.1	0	0	0.1	0	0	0.1	0.1
	325	0.1	0	0	0	0	0	0.1	0	0	0	0

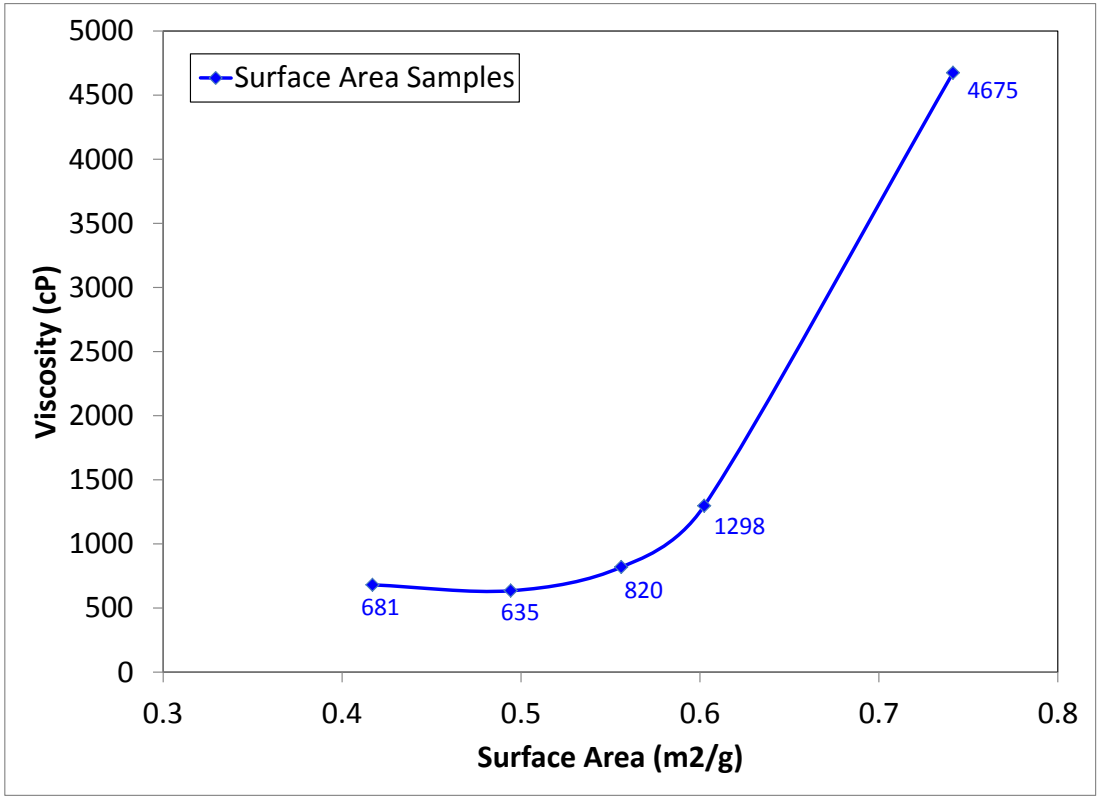
Analytical Analysis – Granulation

- Similar granulation distribution regardless of surface area content
- Distributions are still very broad
  - Further work is required to determine effect on granulation



Brookfield Viscosity

- Based on rotational shear using constant speed
- All samples tested at temperatures just above melting point
  - 97°C – 99°C
- Trend observed in samples
  - Higher surface area results in higher viscosity
- Not unexpected



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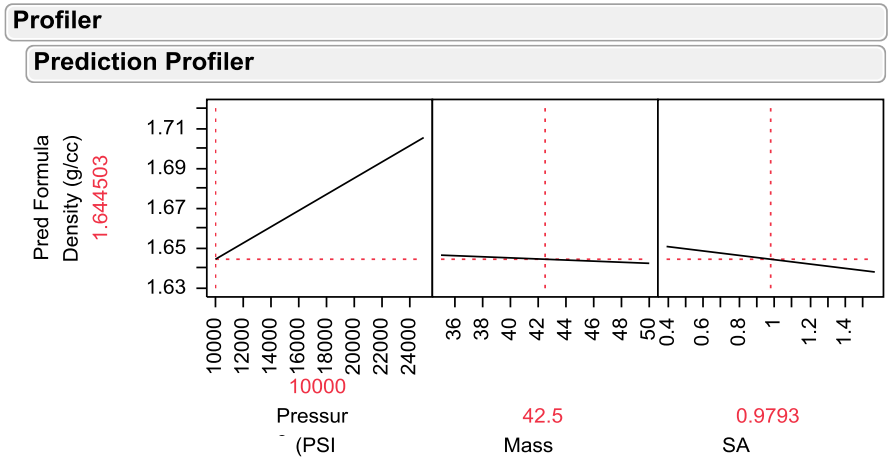
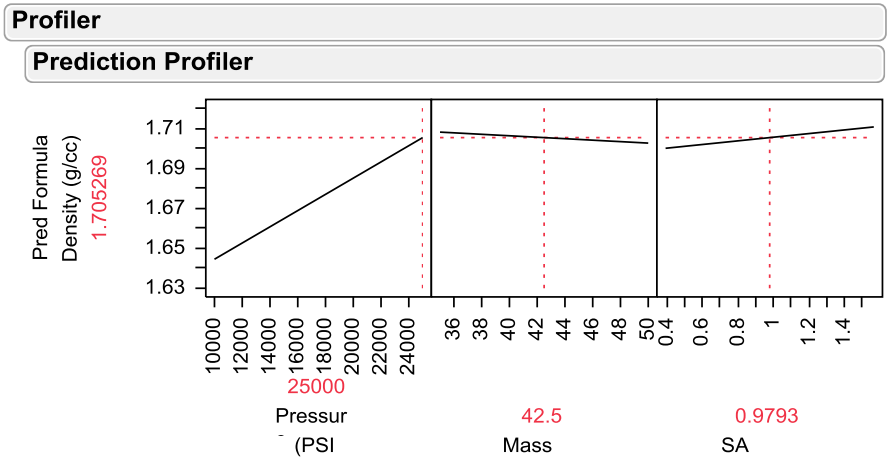
Pressing Study





- I-Optimal DOE
  - Varied pressure, mass, and surface area
  - Indicates pressure is largest factor in controlling pressed density
    - Higher pressure yields higher densities
    - Little or no effect due to mass and surface area
  - Used to determine pressing conditions for LSGT

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Shock Sensitivity – LSGT

- Samples pressed at appropriate conditions to obtain a charge density of approximately 95% TMD

Sample ID	1114-18	1114-20	1114-22	1114-24	1114-26	1114-28	1114-30	1114-32	1114-34	1114-36	1114-38
Charge Density (%TMD)	95	95	95	95	95	95	95	95	95	95	95
50% Point (card gap)	138	Pending	Pending	Pending	Pending	156	Pending	Pending	Pending	Pending	175
Pressure (kbar)	44.6					35.8					28.0
	High Surface Area	→									Low Surface Area

- Additional testing planned for late 2013

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Conclusions and Future Work

- Several generic formulations successfully manufactured at varying surface area values
  - Laboratory process independent of viscosity
    - No significant differences in physical characteristics and processing
    - Granulation can be controlled to obtain useable material
  - Brookfield Viscosity
    - Increases with increase in surface area value
    - Correlation to efflux measurement
  - LSGT
    - Higher surface area resulted in lower sensitivity value
      - 30+ card difference from low surface area sample
    - Further tests planned for late 2013

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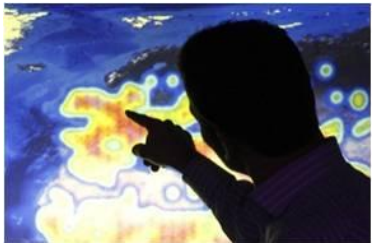

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Questions?