Novel Plasticizer for IM Compliant Solid Propellants

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Physical Sciences Inc.

- 36 year-old company of 180 talented scientists, and engineers
- We work in headquarters in Andover, MA, with five satellite locations in the United States
- Acoustics
- Electro-magnetics
- Fluid physics
- Life sciences
- Chemical sciences
- Energetic Materials
- Optical sciences
- Plasma physics
- Space physics
Nitrofurazan Plasticizers (NF)

- Nitrofurazan family offers promise as high energy, good thermal behavior, high density and low sensitivity plasticizers

\[
\begin{align*}
\text{Nitrofurazan ring} & \quad \text{organic group} \\
\begin{array}{c}
O_2N \\
N
\end{array} & \begin{array}{c}
R \\
N
\end{array}
\end{align*}
\]

NF plasticizers

\[
\begin{align*}
\text{nitrato group} & \quad \text{nitramine group} & \quad \text{butyl group} \\
\begin{array}{c}
O_2NO \\
N
\end{array} & \begin{array}{c}
\text{H}_2 \\
C
\end{array} & \begin{array}{c}
\text{H}_2 \\
\text{N}
\end{array}
\end{align*}
\]

Butyl NENA plasticizer

- NF core: heterocyclic ring with high thermal stability, good density
- Organic Group R: capability to functionalize the nitrofurazanic core
- R group variation may generate various categories of NF plasticizers
Background: NF1

- PSI synthesized and characterized NF1 from low cost precursors (30% yield)
- Aerojet performed the energetic and thermal properties testing: promising plasticizer with good energy and good density

<table>
<thead>
<tr>
<th></th>
<th>Density Gm/cc</th>
<th>Decomposition Temperature, ºC</th>
<th>ΔHf, Kcal/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF1 theor</td>
<td>1.620</td>
<td>180</td>
<td>69.5</td>
</tr>
<tr>
<td>NF1 exp.</td>
<td>1.467</td>
<td>180</td>
<td>58.8</td>
</tr>
<tr>
<td>Butyl NENA</td>
<td>1.211</td>
<td>165</td>
<td>-45.55</td>
</tr>
<tr>
<td>TMETN</td>
<td>1.488</td>
<td>158</td>
<td>-105.8</td>
</tr>
<tr>
<td>BTTN</td>
<td>1.520</td>
<td>154</td>
<td>-92.6</td>
</tr>
</tbody>
</table>
Background: NF1 Cont’d

- NF1 properties
  - Low viscosity fluid
  - Moderate volatility

- Measurements show it is insensitive
  - Category “Green” [normal]

<table>
<thead>
<tr>
<th>Hazard</th>
<th>NF1</th>
<th>RDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact, kg-cm</td>
<td>145</td>
<td>49</td>
</tr>
<tr>
<td>Friction, psi @ drop angle, °</td>
<td>1800 @ 90°</td>
<td>1200@90°</td>
</tr>
<tr>
<td>ESD, J @ 5kv</td>
<td>6.0</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Background: NF1 Cont’d

Onset of weight loss in TGA occurs at a low temperature

Isothermal TGA shows material evaporates after 10 hr at 70°C

Chemical modification to NF1 was required to eliminate volatility
NF1: Background Cont’d

In Differential Scanning Calorimetry (DSC) only endotherms noted due to vaporization – no exotherms
Novel Nitrofurazan Plasticizer: NF2

- Variation of the R group generated various NF classes of nitrofurazanic plasticizers
- R = esteric group: Esteric NF Plasticizers Candidates
- NF2 showed good energy, good density and acceptable volatility
### Novel Nitrofurazan Plasticizer: NF2 Cont’d

<table>
<thead>
<tr>
<th></th>
<th>Density G/cm³</th>
<th>Decomposition Temperature, °C</th>
<th>ΔHf, Kcal/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF2 exp.</td>
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<td>176.4</td>
<td>-62</td>
</tr>
<tr>
<td>NF1 exp.</td>
<td>1.467</td>
<td>180</td>
<td>58.8</td>
</tr>
<tr>
<td>Butyl NENA</td>
<td>1.211</td>
<td>165</td>
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<td>1.520</td>
<td>154</td>
<td>-92.6</td>
</tr>
</tbody>
</table>

NF2 has good sensitivity and good thermal properties.

<table>
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<tr>
<th>Hazard</th>
<th>NF2</th>
<th>RDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact, kg-cm</td>
<td>300</td>
<td>49</td>
</tr>
<tr>
<td>Friction, psi @ drop angle, °</td>
<td>1800 @ 90°</td>
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</tr>
</tbody>
</table>
Novel Nitrofurazan Plasticizer: NF2 Cont’d

In Differential Scanning Calorimetry (DSC) only exotherms were noted: low volatility of NF2
Novel Nitrofurazan Plasticizer: NF2 Cont’d

TGA ISO @ 70°C FOR 16 HRS

NF2 has low volatility: 2% loss in weight at 70 °C for 16 hrs
Novel Nitrofurazan Plasticizer: NF2 Cont’d

Thermal Gravimetric Analysis 1°C MIN

Onset in the weight loss for NF2 starts above 100 °C
Conclusions

- **NF2** has been successfully synthesized and characterized in a 40% overall yield.

- **NF2 synthesis** used low cost precursors and was produced in high purity (>98%).

- **NF2 Testing Results:** insensitive ("green" category material).

- **NF2 showed good thermal properties:** it has good decomposition temperature and low volatility.

- **Additional work will be conducted:** NF2 will be incorporated in propellant samples (work in progress at Aerojet).
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