What about explosivity and flammability of nanopowders?

Safety Parameter Characterisation Techniques for Nanoparticles

Dissemination report
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European Strategy for Nanosafety
Dissemination reports from the Nanosafe2 project are designed to highlight and present in a simplified way the main results obtained in the studies carried out during this project. These reports mainly deal with one question which is of general concern for whom is interested by the safe production and use of nanomaterials. The full results are summarized in the corresponding Technical reports.

All the Dissemination reports and the Technical reports are publicly available from the Nanosafe2 project website: http://www.nanosafe.org

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I. Newly developed apparatus to assess electrostatics hazards and impacts effects

New Hartmann tube to assess electrostatics hazards

Current modified Hartmann tubes (below) used to visualise ignition of powders and to measure the Minimal Ignition Energy (MIE) are made of a transparent material (glass or plexiglass) and are open ended. This kind of equipment is not well suited for nanopowders because of potential emissions of nanoparticles during the experiment. Therefore a closed stainless steel tube has been designed to withstand an explosion pressure up to 12 bars. This tube is equipped with a pressure sensor. To prevent all kind of contamination with the exterior of the explosion chamber, a computer driven data acquisition and a specific self confined cleaning procedures (by propane combustion, and air pulses) have been developed.

New falling hammer device to assess impact effects

Mechanical impact on powders may result in explosion. Current test cells allow the operator to detect explosion either by visual or by auditory means. Such techniques are not adequately suited for nanoparticles. Hence, a new confined cell equipped with pressure and four thermocouple sensors, to assess nanopowder sensitivity to impact, was built and computer monitored with a specific software.

New confined stainless steel Hartmann tube and falling hammer equipment help bring experiments to a higher degree of safety and efficiency.
II. Explosion violence and flammability of nanopowders

Explosion sensitivity (Minimum of Ignition Energy, « MIE » - Minimal Explosion Concentration « MEC») and Explosion Severity (maximum pressure of explosion and maximum rate of pressure rise – Kst) of various carbon black powders (Corax N115, Thermal Black N990, Corax N550 and Printex XE2), aluminum nanoparticles of different sizes and carbon nanotubes (CNT) were assessed using a 20 l spherical vessel (illustrated below) in accordance with current practices such as the American Society for Testing and Materials (ASTM) Method E 1226, National Fire Protection Association (NFPA) Standard 68 (1994) or German Society of Engineers (VDI) Method 3673 (1995).

![20 l explosion sphere](image)

Explosion severity and Explosion sensibility of studied nanopowders.

<table>
<thead>
<tr>
<th>Products</th>
<th>Carbon blacks</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CNT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corax N115</td>
<td>Corax N550</td>
</tr>
<tr>
<td>MIE (mJ)</td>
<td>&gt; 1J</td>
<td>&gt; 1J</td>
</tr>
<tr>
<td>MEC (g/m³)</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Pmax (bars)</td>
<td>6.6</td>
<td>7.7</td>
</tr>
<tr>
<td>(dP/dt)max (bars/s)</td>
<td>227</td>
<td>326</td>
</tr>
<tr>
<td>Kst</td>
<td>62</td>
<td>88</td>
</tr>
<tr>
<td>Explosivity Class</td>
<td>St1</td>
<td>St1</td>
</tr>
</tbody>
</table>

Lesson: Studied carbon nanotubes exhibit explosion severities and sensitivities of the same order of magnitude as those found for various coals, food flours and other nanostructured carbon blacks.

Lesson: For metallic aluminum nanopowders, the small oxyde layer wrapping passivated nanoparticles may make them less explosible than micropowders.

Lesson: Nanopowders which tend to agglomerate show explosion violence characteristics of the same order of magnitude as those observed with micropowders of the same substance.
III. Onset combustion temperature

Oxidation of the carbon nanotube (CNT) material was investigated by means of isothermal thermogravimetry and thermal differential analysis (see below). Onset oxidation temperature (i.e. at the beginning of the reaction) of CNTs and carbon blacks were evaluated at various heating rates (0.5, 1, 2, 5K/mn) in order to determine reaction kinetic parameters that can be used to assess self heating behaviors.

Differential scanning calorimetry and isothermal kinetic studies of the oxidation of nanoparticles.

Temperature onset of the combustion as a function of the specific surface area

Lesson: Onset temperature of carbon materials strongly depends on the specific surface area of those materials.

The decrease of temperature onset with the increase of the specific surface area can be explained not only by the increase of the specific surface, but also by the potential decrease of the activation energy of the combustion reaction between carbon and oxygen.
A similar phenomenon is also observed for aluminum as shown by the synthesis of literature data on the following figure. The temperature at which the oxidation of aluminum begins, drastically decreases (about 200-300°C) when the particle size decreases. When a nanometric size is reached, combustion begins before the aluminum melting temperature (660°C).

![Aluminum oxidation temperature onset as a function of particle size (logarithmic scale).](image)

**Warning:** For aluminum, combustion mechanisms of nanosized particles are different from those observed with microsized particles. This may lead to potential problems of large scale industrial storage of such particles.

**Advice:** Specific prevention and protection measures should then be taken.
Nanosafe2 brings together twenty five partners from seven different countries of the European Union, mainly small, medium and large enterprises and public research laboratories. The project is supported through the Sixth Framework Programme for Research and Technological Development and addresses the thematic priority 3.4.3.2–1: Hazard reduction in production plant and storage sites. The project has started in april 2005 and will end in march 2009.

Nanosafe2 main objective is to develop risk assessment and management for secure industrial production of nanoparticles. It focuses on four areas: Detection and characterisation techniques, Health hasard assessment, Development of secure industrial production systems and safe applications, Societal and environmental aspects.

**Partners**

http://www.nanosafe.org
What about explosivity and flammability of nanopowders?

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One of the main questions asked about nanopowders, when it comes to explosivity and flammability, is: Do nanopowders behave like other powders and, as such, can they more readily ignite and explode? During this study, carried out in the frame of the European Nanosafe2 project, safety parameters of nanopowders and their associated techniques and practices have been characterised for a representative set of particles of industrial relevance.

Lesson: New confined stainless steel Hartmann tube and falling hammer equipment help bring experiments to a higher degree of safety and efficiency.

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