Measurement of the Dustiness of Nanoparticle Powders with a Modified Single-Drop Tester

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Background

Dustiness is the propensity of a powder to produce airborne dust as a result of handling.

Having detailed information about the propensity for nanoparticles to become airborne if emitted as fugitive dust is necessary to fully characterize risks involved with nanomaterial production.

Standard methods for determining dustiness of powders have been developed in Europe, but not in the U.S.

The German standard (DIN 55992-2) describes the single-drop method to determine dustiness index for pigments and fillers.

This study was motivated by the need for a nanopowder dustiness measurement technique that utilized milligram quantities of test dust (expensive nanopowders) and could size-segregate particles in the dust cloud (dustiness calculation).

Objective

To develop a modified single-drop dustiness-testing device that could meet the criteria stated above and test it by comparing the dustiness of powders with primary particle sizes below 100 nm relative to the dustiness of other common powders.

Methods

A single-drop dustiness-testing device was developed similar to that recommended in DIN 55992-2.

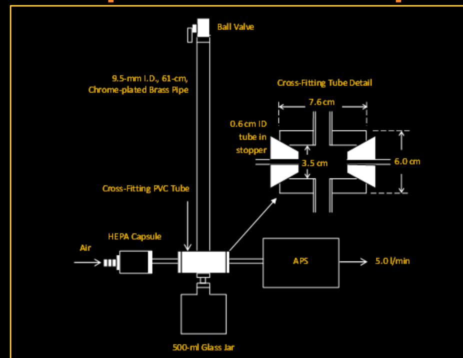
An APS was used to measure the particle size distribution of the falling powder and enable respirable and mass fractions to be calculated.

Adding the APS differed from the German standard which utilizes a passive photometer to measure the ensuing dust cloud flowing past the view volume of photometer.

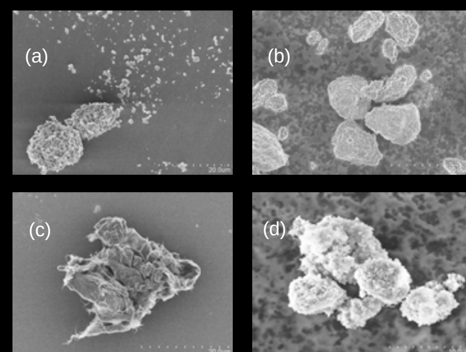
Three trials were conducted for each powder type – each trial used 15 mg of given powder sample.

Ten nanoparticle powders and four other powders were tested.

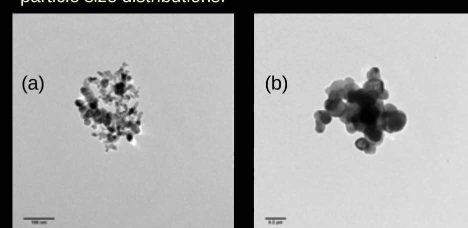
Experimental Setup



Schematic of the modified single-drop dustiness-testing device.



Scanning electron micrographs of particles resulting from the following powders: (a) 5-nm TiO_2, (b) Fe_2O_3, (c) single-wall carbon nanotubes, and (d) SiO_2 to show particle size distributions.



Transmission electron micrographs of (a) 21-nm TiO_2 and (b) reagent-grade TiO_2 to show primary particle size.

Agglomerates can be closely packed [e.g. SEM photo (b) of Fe_2O_3] or loosely structured [e.g. TEM photo (a) of 21-nm TiO_2].

Results

Powder	Median Size (nm)	Inhalable Dustiness (mg/kg)	Respirable Dustiness (mg/kg)
Nanopowders			
Al_2O_3 whiskers	2-4 x 2800	486 (296)	91 (40)
Al_2O_3	10	6142 (196)	289 (12)
Al_2O_3	50	1332 (122)	347 (70)
Carbon Black	14	1680 (171)	558 (134)
Cu	25	162 (46)	96 (28)
Fe_2O_3	35	626 (234)	205 (72)
SiO_2	20	5247 (1074)	2256 (248)
SWCNT	1-2 x 15,000	2070 (386)	366 (34)
TiO_2	5	5958 (539)	464 (72)
TiO_2	21	4606 (753)	348 (39)
Other Powders			
ARD	9100	271 (51)	165 (22)
Cloisite® 20A	6000	1509 (566)	786 (307)
Nanofil® 5	10,000	1271 (86)	806 (56)
TiO_2 (Reagent)	NR	1242 (753)	212 (141)

Inhalable and Respirable Dustiness Mass Fractions with Standard Deviation

Discussion and Conclusions

ANOVA analysis for respirable and inhalable concentrations revealed significant difference between powder types ($p<0.0001$).

SiO_2 produced significantly higher respirable concentrations than all other dusts (Tukey's procedure).

5-nm TiO_2, 21-nm TiO_2, 10-nm Al_2O_3, and SiO_2 produced highest inhalable concentrations.

The TiO_2 powders demonstrated a decline in inhalable concentration (and dustiness fraction) with an increase in particle size.

Differences in dustiness values between those reported here and those of other studies emphasizes the need to establish two well-characterized test powders that can be applied to any device that, together, represent the extremes in powder dustiness.

Applying the same two powders will gage results so that they can be normalized to those of a chosen standard for occupational health risk assessment.

Acknowledgements

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