

Team Gas Sensor NO₂: Primary Discussion Points

- Assumptions
 - Polyaniline and hydroxylated SHOULD interact with NO_x
 - Degree of interaction corresponds to magnitude of resistive changes
 - Vapor functionalization post-processing
 - Device will be conductive
 - Customers
 - Airports, highways, power generation plants, IoT?
 - Bluetooth connectivity, battery operated
 - Mapping NO₂ levels throughout a city

Team Gas Sensor NO₂: Primary Discussion Points

- Factors impacting the reproducibility of the manufacturing method and final product
 - Dynamic range will be limited and needs to be tested
 - A lot of variability with drop-cast tubes
 - Variability in the tubes used in the process
 - Baseline measurement of resistance is required for each sensor
 - To reduce drift, keep the sensor above ambient high temp (also reduces Temp dependency)
- Factors to consider when choosing materials (e.g., cost, purity, source)
 - Quality control on CNTs is terrible
 - May need to remove surfactants, metal impurities, etc.
 - Polyaniline is very toxic
- The plan for testing, including field/test conditions, regulatory requirements, scope, etc.
 - Need to calibrate sensor
 - You can purchase a calibrated gas standard for NO₂, but need to worry about potential interferences (particulates, other chemicals)
 - Very important to do field tests to avoid ants, eagles or any other unexpected visitors

Team Gas Sensor NO₂ : Other Considerations (1 of 2)

- Factors impacting the scalability of the manufacturing method
 - Drop-cast method should be highly scalable, roll to roll could be used
 - Needs to be modified to speed up manufacturing process – mass produced
- Limitations in terms of raw materials and processing technologies
 - NO_x does not selectively interact with many CNTs
- Manufacturing cost drivers for this technology
 - Seems to be pretty reasonable
- Remaining technical issues hindering commercialization of this technology
 - Need to include a front-end filter to keep particles out of the sensor
 - Design includes a fan and heater, paper says it could be removed
 - No heater means it is a one-time measurement
 - But heater would also remove organics (eventually NO₂!) and humidity
 - Sampling height?

Team Gas Sensor NO₂ : Other Considerations (1 of 2)

- Factors that will influence the decision to manufacture in-house vs. contracting out
 - In-house manufacture is not sustainable
 - 120 um gap can be screen printed to speed up production, combined with roll to roll
- Life cycle considerations (e.g., device or effluent disposal)
 - Are we assuming the sensor is stable? Even with humidity and other contaminants
- Major safety concerns for manufacturing the sensor
 - CNTs dried during manufacture is a concern
 - Aniline is a concern
 - Durability during rain, acid rain, UV exposure, thermal gradients
- Other (please specify)
 - Wildlife interference?

Test selection for durability (aqueous due to rain events)

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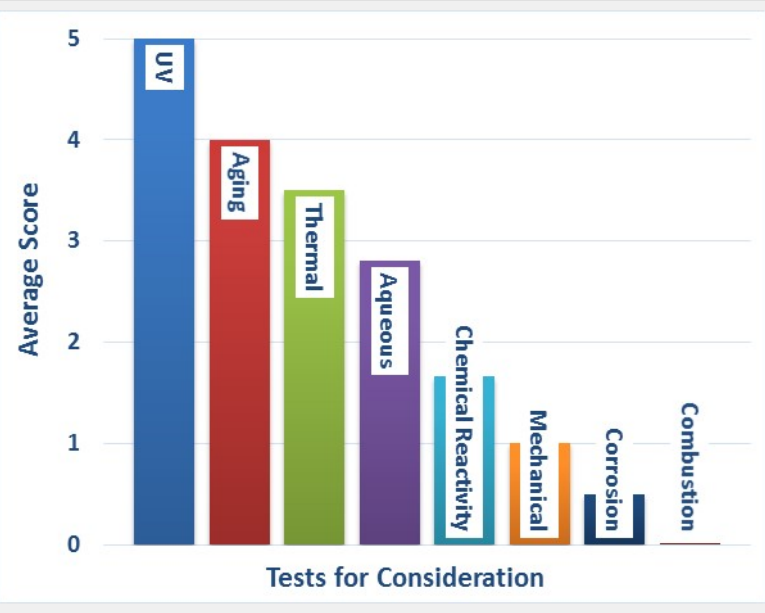
Release Hazard Identification Testing Identification Help documentation

Each question on the tabs below is linked to a release test that should be considered. Rate 0 if there is no chance the test could be necessary if the product is used as intended and 5 if the product will definitely need to be tested under that condition. Provide justification in the associated text boxes to ensure transparency in your responses. By default, the most conservative assumption (5) is selected.

Aqueous Ultraviolet Thermal Aging Mechanical Combustion Chemical Reactivity Corrosion Test Consideration Test Selecti

The goal of this graph is to help show you the types of tests that you will want to consider based on the answers to the other tabs in this section. This list is by no means exhaustive to all the tests that could be performed, but more or less represents the general tests that one should consider. If you are still having trouble deciding which tests to move forward with, try clicking the button below for a decision tool that incorporates factors such as cost and time.

Test Selection Tool



Test	Average Score
UV	5
Aging	4
Thermal	3.5
Aqueous	2.8
Chemical Reactivity	1.7
Mechanical	1.0
Corrosion	0.5
Combustion	0.2

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MCDA combinational testing output

MCDA Test Selection Tool

Tests Selection | Scores | Weights | MCDA Results

Instructions

You may edit the value weights for the criteria to reflect how important each criterion is to you. Criteria that are more important to you should be given a higher weight. The sum of the weights for all four criteria must equal 1.

	Weights:	Normalized weights:
Duration:	<input type="text" value="0.25"/>	<input type="text" value="0.25"/>
Magnitude:	<input type="text" value="0.25"/>	<input type="text" value="0.25"/>
Cost:	<input type="text" value="0.25"/>	<input type="text" value="0.25"/>
Expertise:	<input type="text" value="0.25"/>	<input type="text" value="0.25"/>
Sum:	<input type="text" value="1.00"/>	<input type="text" value="1.00"/>

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Release | Hazard Identification | Testing Identification

Help documentation

Each question on the tabs below is linked to a release test that should be considered. Rate 0 if there is no chance the test could be necessary if the product is used as intended and 5 if the product will definitely need to be tested under that condition. Provide justification in the associated text boxes to ensure transparency in your responses. By default, the most conservative assumption (5) is selected.

Thermal | Aging | Mechanical | Combustion | Chemical Reactivity | Corrosion | Test Consideration | Test Selection and Results

Condition	Rating
UV & Water	4.5
Thermal & Water	4.5
Sunlight Exposure	3.5
Temperature Flux	3.0
Humidity Changes	2.5
Rain Event	2.0
Temperature Elevation	2.0
Temperature Reduction	2.0
Aging	2.0

Test 1 | Test 2 | Test 3 | Test 4

You may perform either a simple test, or a combinational test. Use the first row of inputs below to report the results of a single test, or multiple rows for each stage in the case of a combinational test. Click 'Browse' after selecting a test method to view its specification online. Please record whether you observed the release of the nanomaterial by selecting 'Yes' or 'No'. You may also describe the release or provide justification for choosing this test.

Test:	Test method:	Browse	Released?	Describe the release:
Rain Event		Browse	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Sunlight Exposure		Browse	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Temperature Flux		Browse	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Humidity Changes		Browse	<input type="radio"/> Yes <input checked="" type="radio"/> No	

Additional:

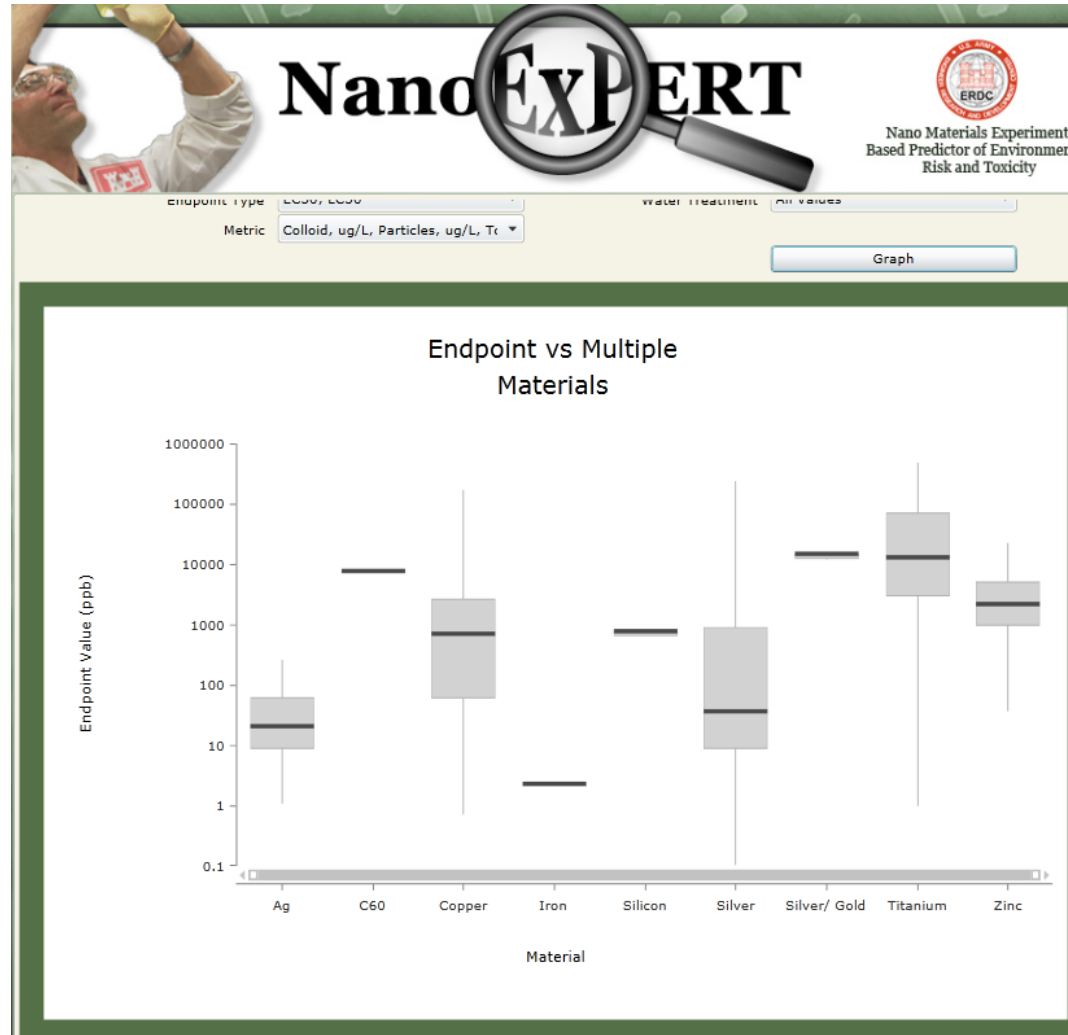
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Tiers 2/4: CNTs low environmental hazard; large occupational hazard concern during manufacturing depending on “dustiness” level

aniline is hazardous (non-nano-concern)



Gas sensor to measure NO₂
in air

Use of nano-enabled technology structure category cannot be excluded from regulatory testing

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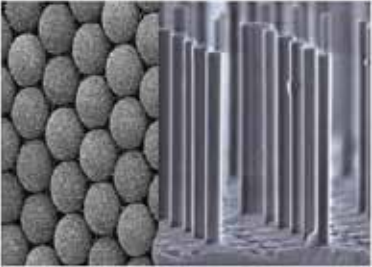
Basic Information Technology Category Nanomaterial Definition Special Properties Help documentation

Instructions
Please read the description of each of the nano-enabled technology categories by clicking on each of the tabs below. Then use the dropdown menu at the bottom to select the most applicable technology category to your product. You may only select one technology category. If multiple technology categories apply, please start a separate profile of NanoGRID for that technology category and run that technology category through the process separately.

Bulk			Surface Bound			Particles			
1A	1B	2A	2B	2C	3A	3B	3C	3D	

Category 3A: Surface bound Nano-object (particles, rods, diamonds etc.) 2 Dimensional Structure (Multi Type)

This category consists of a surface bound nano-objects. The nanoscale object dimensions range from roughly 1 to 100 nanometers and extend in two spatial dimensions. This category is made up of multiple types of material.



Category 3A: Surface bound Nano-object (particles, rods, diamonds etc.) 2 Dimensional Structure (Multi Type)

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Use of nanoparticle cannot be excluded from regulatory testing

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Basic Information Technology Category Nanomaterial Definition Special Properties Help documentation

Instructions
Please select all of the following that apply. If you are unsure of an answer, you may use a precautionary ("conservative") approach by checking the box next to the question(s).

Solid at 25 °C and 1 atmosphere and at least 1% of the total particles (A) by mass (US EPA TSCA Section 8) or (B) by particle number (EU 2011) has a primary particle size that is less than or equal to 100 nm in at least one dimension.

The material is a nanomaterial, as defined above, and the average aggregate size is less than 1000 nm in at least one dimension

There is strong evidence that there is aggregation or sintering (irreversible size increase) such that the average aggregate size is greater than 1000 nm

If there is aggregation or sintering there may be an argument that the materials are no longer nano-sized. However, you must have a very strong rationale in the text box below. If you have strong rationale and this is the only check box, you may wish to determine if further nano-specific regulatory scrutiny or testing is required.

The average volume specific surface area of the material is greater than $60 \text{ m}^2 / \text{cm}^3$ (Kreyling et al 2010)

The nanomaterial displays size-dependent unique/novel properties that are a result of its size in at least one of the following categories:

- Strength
- Magnetism
- Chemical reactivity
- Electrical conductance
- Heat conductivity
- Light reflection
- Color
- Melting point
- Fluorescence

For more information on these nano-enabled technology categories to inform your selection, please see the following resources:

Kreyling WG, Semmler-Behnke M, Chaudhry Q. 2010. A complementary definition of nanomaterial. *Nano Today* 5:165-168.
<http://www.sciencedirect.com/science/article/pii/S1748013210000460>

European Commission. Commission recommendation of 18 October 2011 on the definition of nanomaterial. 2011. Official Journal of the European Union. 2011/696/EU.
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:275:0038:0040:EN:PDF>

Surface Area Analysis Using the Brunauer-Emmett-Teller (BET) Method (2016). Brame, J.A., Griggs, C.S. (No. ERDC/EL SR-16-3)
<https://erdc-library.erdc.dren.mil/xmlui/handle/11681/20339>

US EPA TSCA Section 8a
<https://www.federalregister.gov/documents/2017/01/12/2017-00052/chemical-substances-when-manufactured-or-processed-as-nanoscale-materials-tsc-reporting-and>

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Perform tests: Low release potential?

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Release Hazard Identification Testing Identification Help documentation

Product Classification and Use

Is the product a freely dispersed particle (product class 3B or 3D)?

Conservative Release Scenario

Does your material have a known Predicted No Effect Concentration?

Would you like to first generate hazard data / screening values (skip to Tier 4) or would you prefer to proceed without it and generate release data (continue/complete Tier 2)?

Testing Identification

Perform release testing per results of Testing Identification tab in order to quantify the potential release under a realistic use scenario.

Release Data Generation & Analysis

After characterizing released material per Martin et al., were nanomaterials released either in a free form or a matrix-bound form that still meets the definition of 'nano'?

This may suggest low risk/concern. It is recommended that you stop here (click 'Generate Report' to save your findings). Keep in mind, however, that the toxicity of matrix-bound material may be different from that of the pristine nano-scale ingredient. If you would like to continue characterizing the EHS implications of your product, you may proceed to Tier 3 by clicking 'Continue'.

Hazard values entered for demonstration purposes: need to consider CNT dustiness, worker inhalation risk during manufacturing (while material is dry)

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Release Hazard Identification Testing Identification Help documentation

This page is designed to help screen your material for potential hazard level. Here we will use Simple Box for Nano to compute a Predicted Environmental Concentration (PEC) and compare it to a Probable No Effect Concentration (PNEC).

Environmental Hazard Screening Human Health

Human Health

Effect values for Inhalation: Units

Effect values for dermal:

Effect values for Ingestion:

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