

Characterization and Control of Airborne Particles Emitted During Production of Epoxy Reinforced With Carbon Nanotubes

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Background

Adverse pulmonary, cardiac and dermal health effects may be associated with exposures to carbon nanotubes (CNTs)

CNTs are often embedded in polymeric materials to enhance commercial products

CNTs must be weighed and composite materials (e.g., CNTs in epoxy resin) must be processed (e.g., sanded) to arrive at a final product

Enclosures such as fume hoods are often used to protect workers during production

Results

Nanoparticle Number Concentrations

a. Weighing								
Breathing Zone					Inside Enclosure			
Location	N	GM #/cc	GSD	Ratio to background	N	GM #/cc	GSD	Ratio to background
Glove Chamber	n/a	n/a	n/a	n/a	300	166	1.08	1.06
b. Sanding								
Fume Hood	210	1989	1.07	1.03	211	1742	1.05	1.01
Work Table	100	3889	1.48	1.04	n/a	n/a	n/a	n/a
Biosafety Cabinet	101	1350	1.07	1.05	108	0.06	2.41	2.35

Negligible number concentration compared to background indicates nanoparticles not dispersed to any great extent by weighing or sanding in these tests

Respirable Mass Concentrations

a. Weighing								
Breathing Zone					Inside Enclosure			
Location	N	GM $\mu\text{g}/\text{m}^3$	GSD	Ratio to background	N	GM $\mu\text{g}/\text{m}^3$	GSD	Ratio to background
Glove Chamber	n/a	n/a	n/a	n/a	51	0.03	3.50	1.79
b. Sanding								
Fume Hood	190	21.4	5.85	24.4	93	31.5	12.1	28.6
Work Table	130	2.68	6.57	5.90	n/a	n/a	n/a	n/a
Biosafety Cabinet	101	0.20	2.12	0.66	108	0.03	39.7	3.47

Sanding epoxy generates airborne particulate, however respirable mass concentrations are low (particles not otherwise specified TLV – 3,000 $\mu\text{g}/\text{m}^3$)

Objectives

Characterize airborne particles emitted from weighing CNTs and sanding epoxy containing 2% by weight CNTs

Evaluate effectiveness of control measures to protect workers when sanding epoxy containing CNTs

Methods

Tasks:

- Weighing bulk multi-wall CNTs
- Sanding epoxy containing multi-wall CNTs

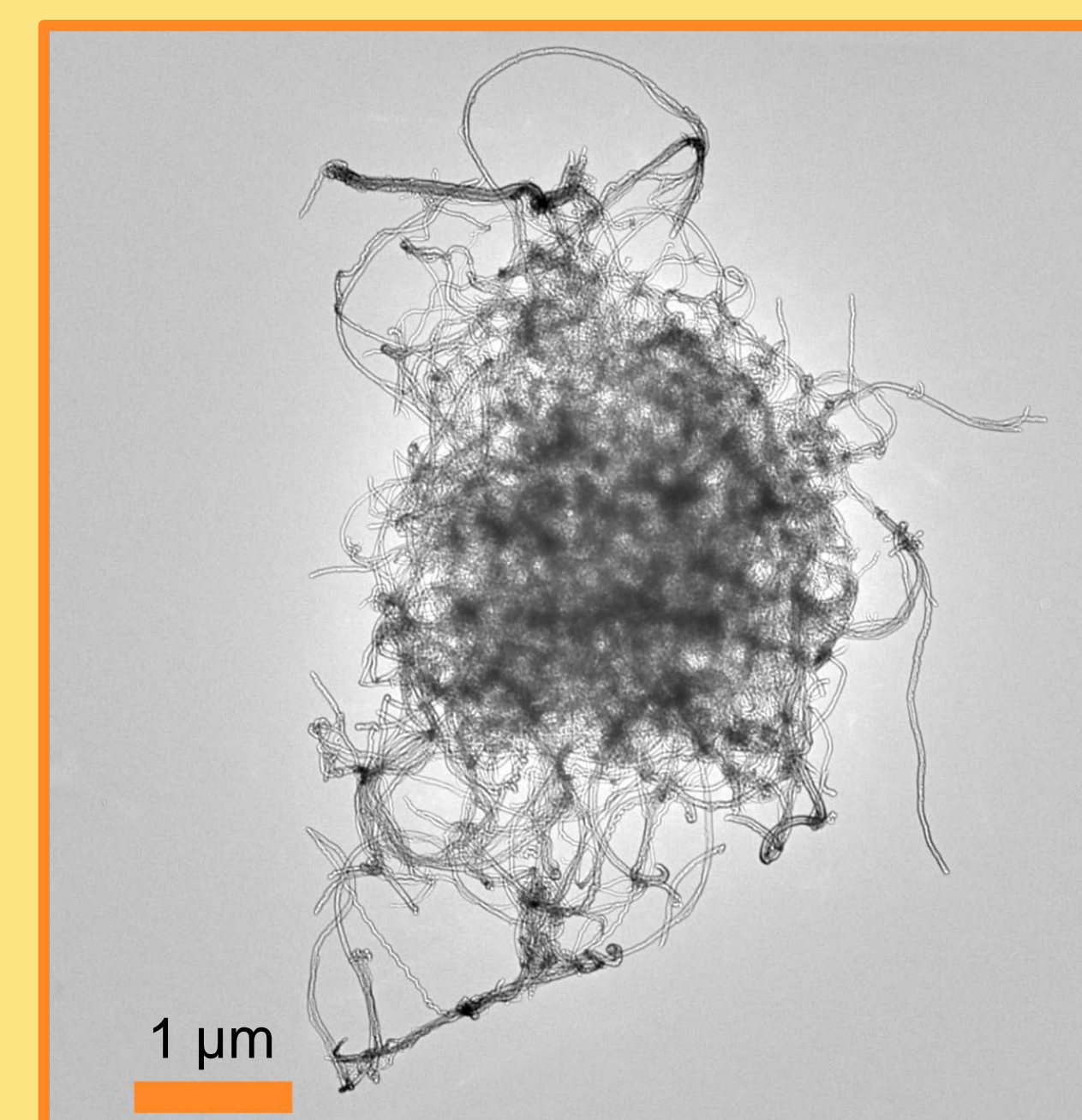
Measurements:

- Number concentrations
TSI 3007 CPC (10 nm – >1 μm)
- Respirable mass concentrations
Grimm 1.108 OPC (0.3 μm – 20 μm)
- Morphology by transmission electron microscopy

Control Measures (sanding only):

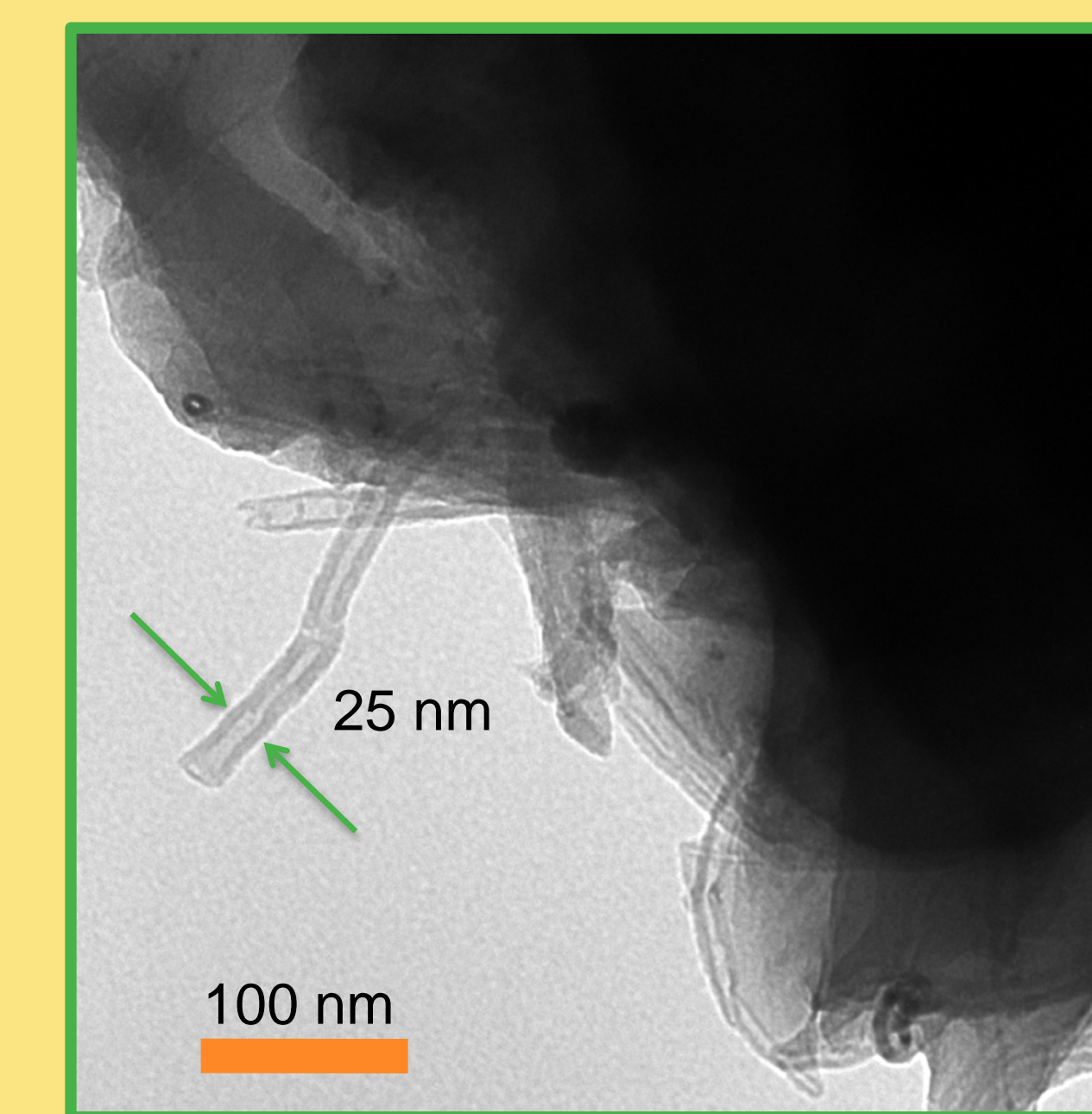
- Fume hood
- Biosafety cabinet
- No control (work table)

Comparison of particle morphology

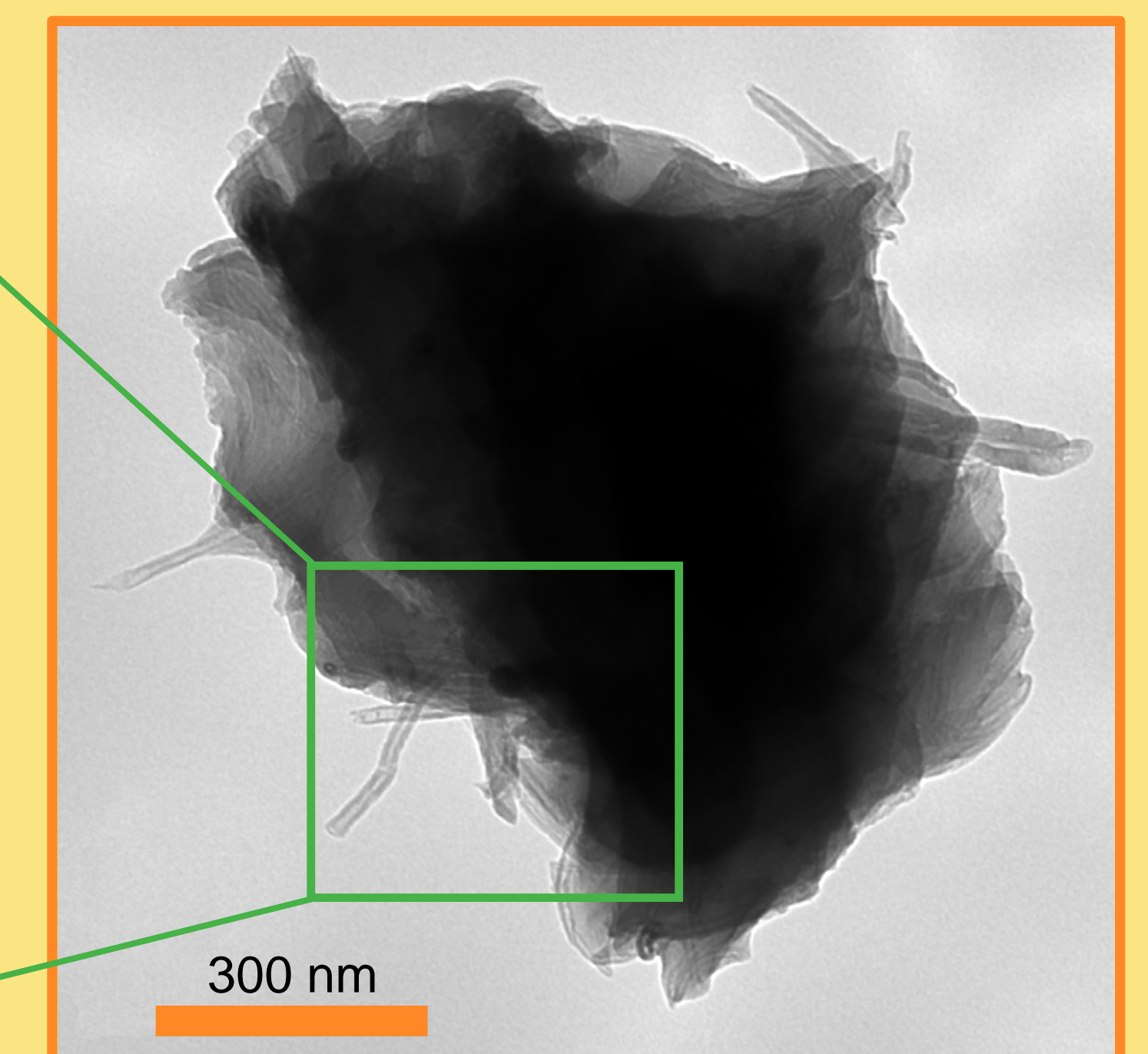


Bulk multi-wall CNTs with many tangled nanotubes

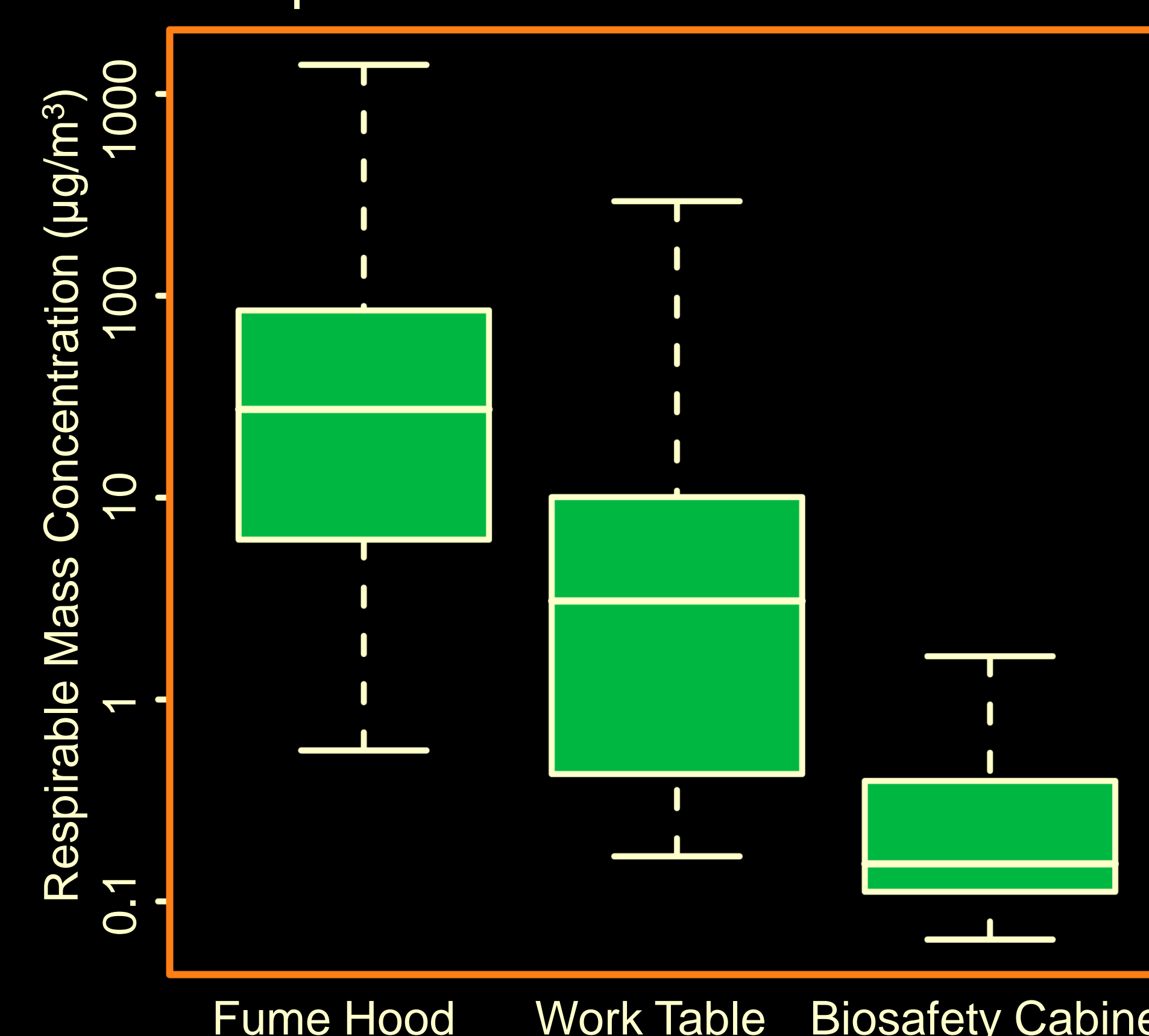
Large particles from sanding epoxy are very different from bulk multi-wall CNTs



Dust particle from sanding with nanotubes protruding from surface



Comparison of control measures



All control measures significantly different pairwise comparison p-values < 0.0001

Concentrations lower at work table than fume hood probably due to air flow patterns around worker

Lowest concentrations observed in biosafety cabinet

Conclusions

Production of epoxy containing CNTs emitted airborne particles larger than 300 nm

Substantially more particles emitted in sanding of composite epoxy than in weighing bulk material

Biosafety cabinet more effective than fume hood at controlling respirable mass concentrations

Future Research

Characterize airborne particles emitted during production of other nanocomposite materials