McGill UNIVERSITY

Quantitative Stability Analyses of Multiwall Carbon Nanotube Nanofluids following water/ice phase change cycling

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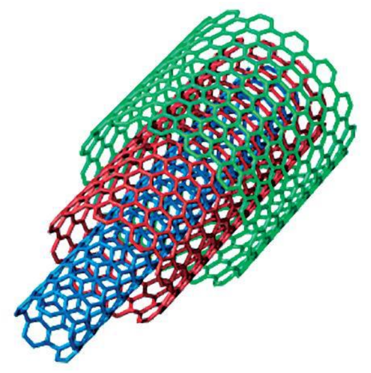
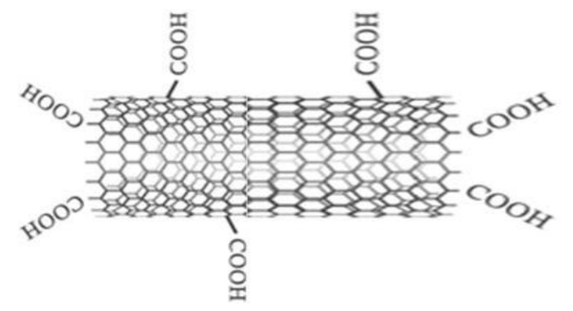
Introduction

- Multiwall carbon nanotube (MWCNT): concentric sheets of graphene. L=1 um, W=30 nm
- Aqueous MWCNT-nanofluids possible due to oxygen functionalization of MWCNT surface
    - Negative surface charge in water
- In freezing applications (latent heat thermal energy storage, gas hydrates)
    - accelerated nucleation, rates of sensible cooling, crystallization, increased conversion
- Success of nanofluid technologies depends on ability to retain stable dispersion

- **Problem:** Loss of stable dispersion upon freezing





Research Question

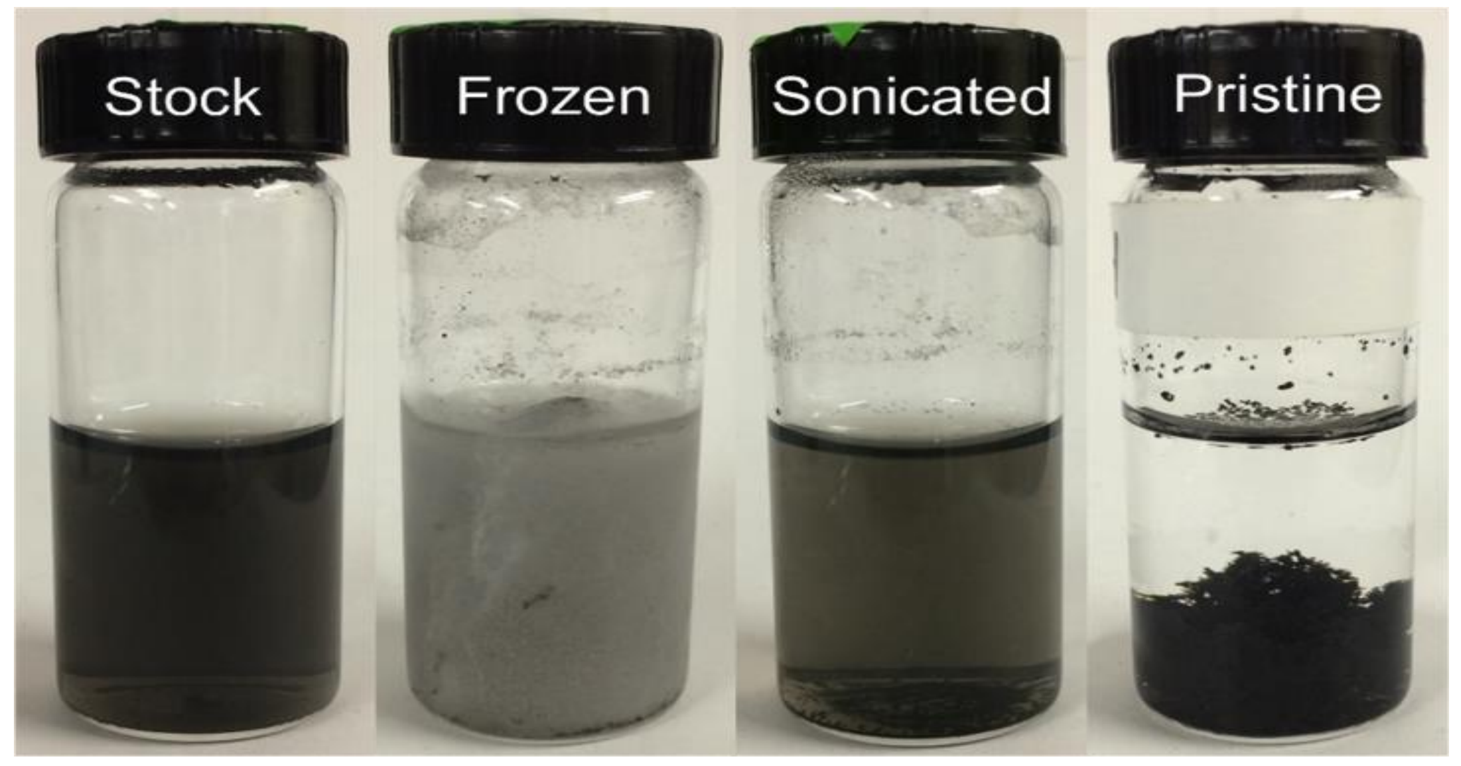
- Assess stability of oxygen functionalized MWCNT nanofluids over repeated phase change cycling
    - Use of ultrasonication to restore dispersion

- Employ quantitative metrics to characterize stability

Experimental Schedule

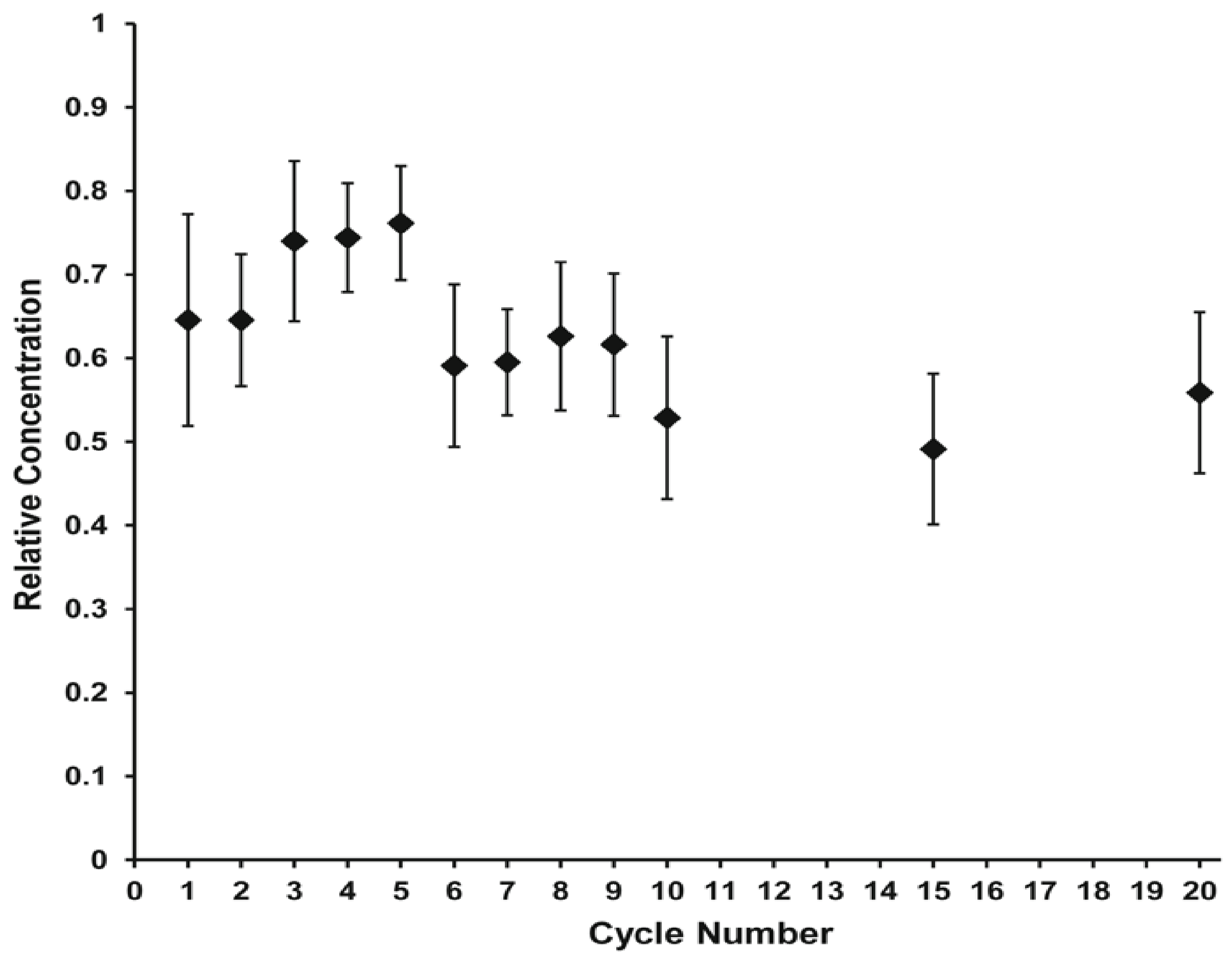
Time	Procedure
9:00 – 10:30	Samples removed from freezer and thawed
10:30 – 11:30	Samples sonicated
11:30 – 14:00	Particle size measurements
14:30 – 15:30	Zeta potential & UV-Vis measurements
16:00	Samples placed in freezer (-23 °C) overnight

Six samples tested, concentrations 15 – 91 ppm

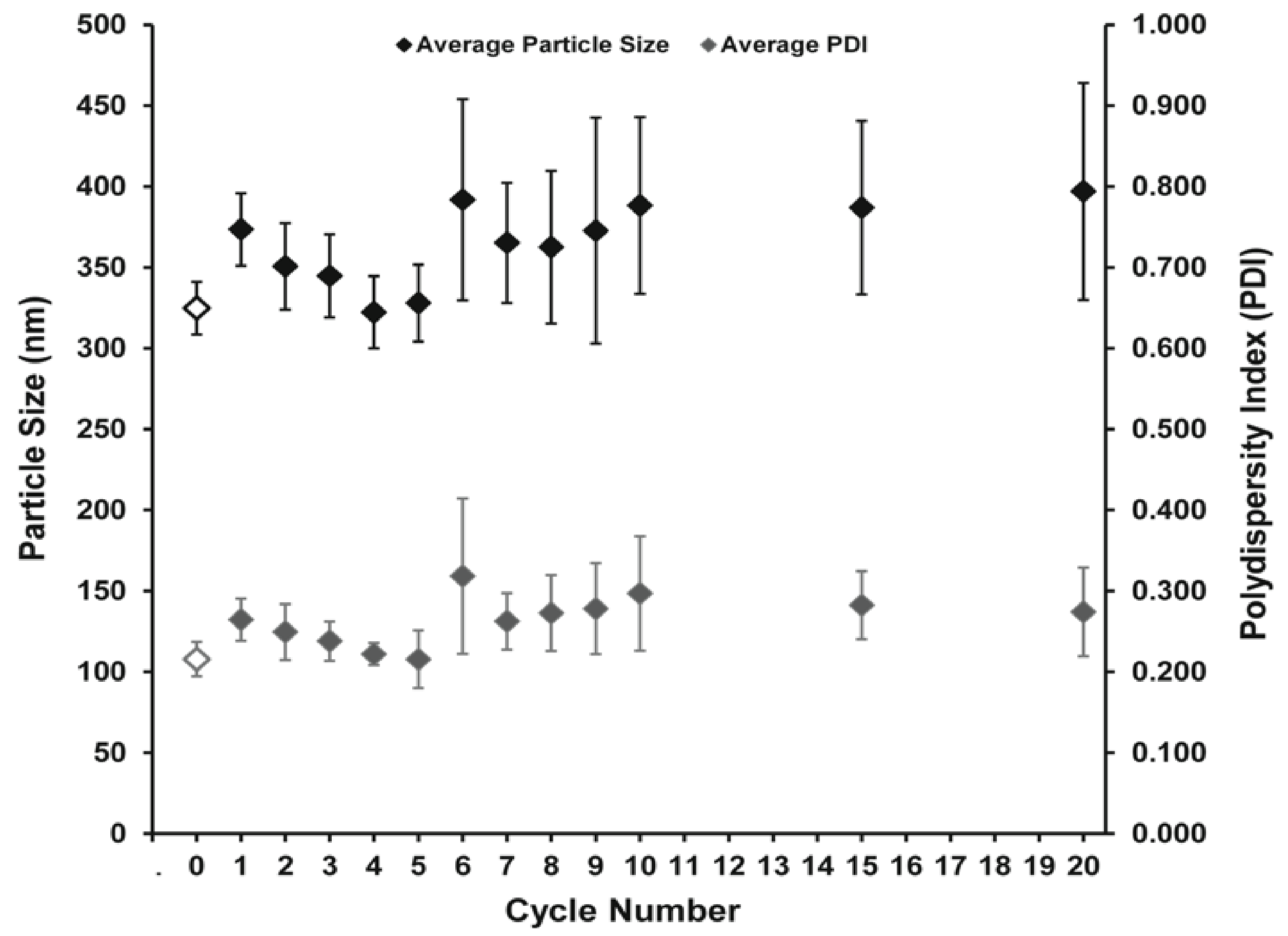


Results

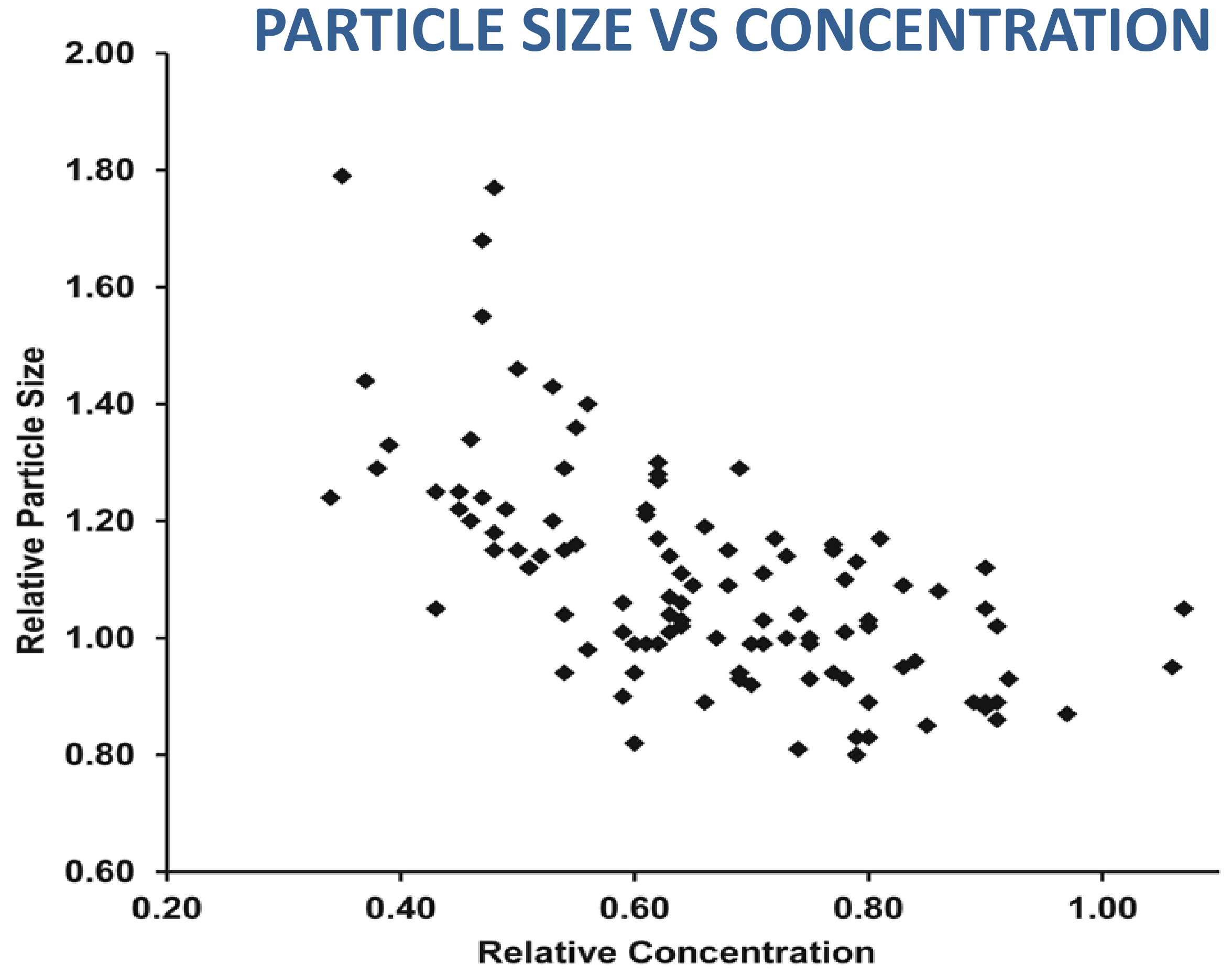
CONCENTRATION



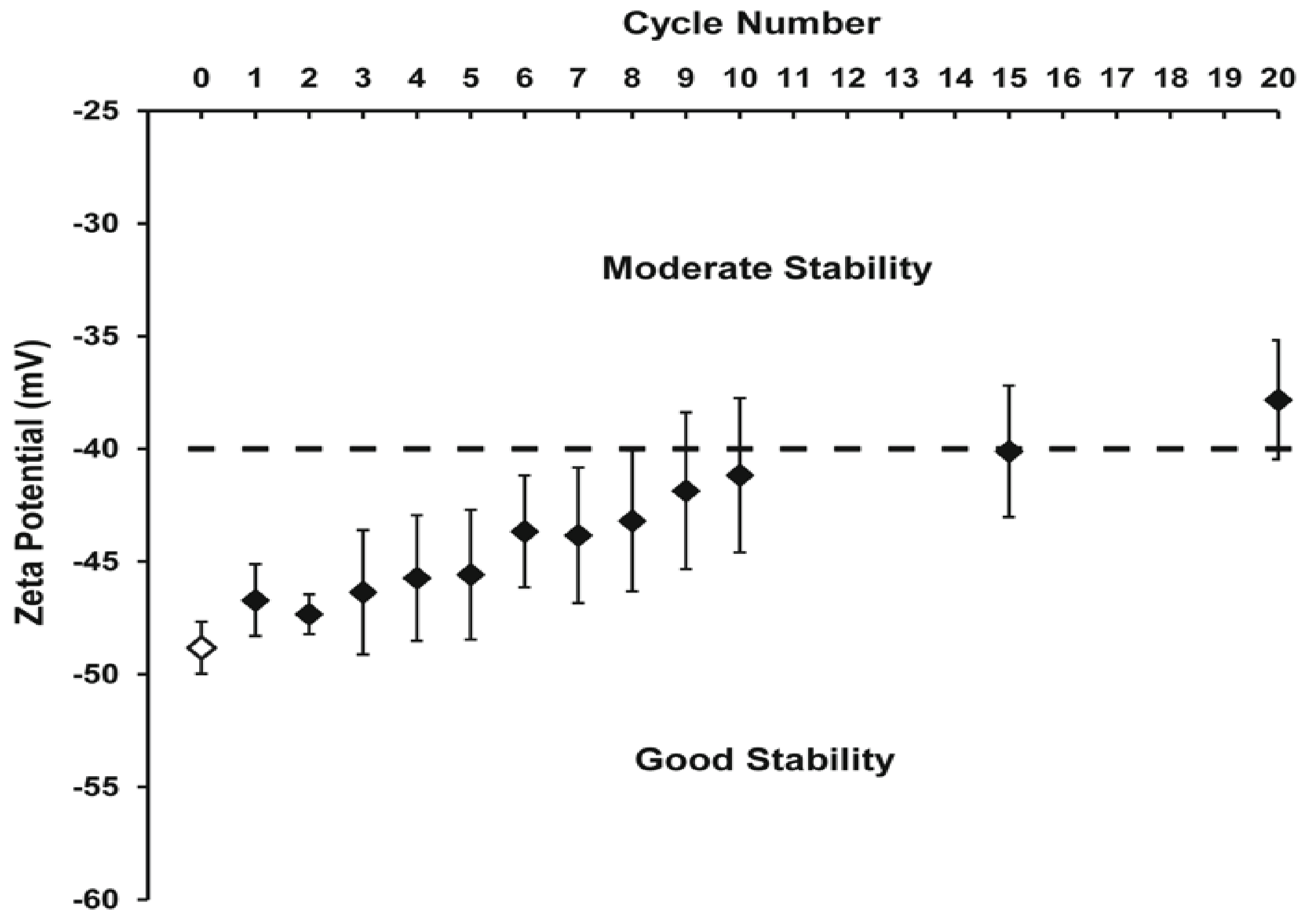
PARTICLE SIZE



PARTICLE SIZE VS CONCENTRATION



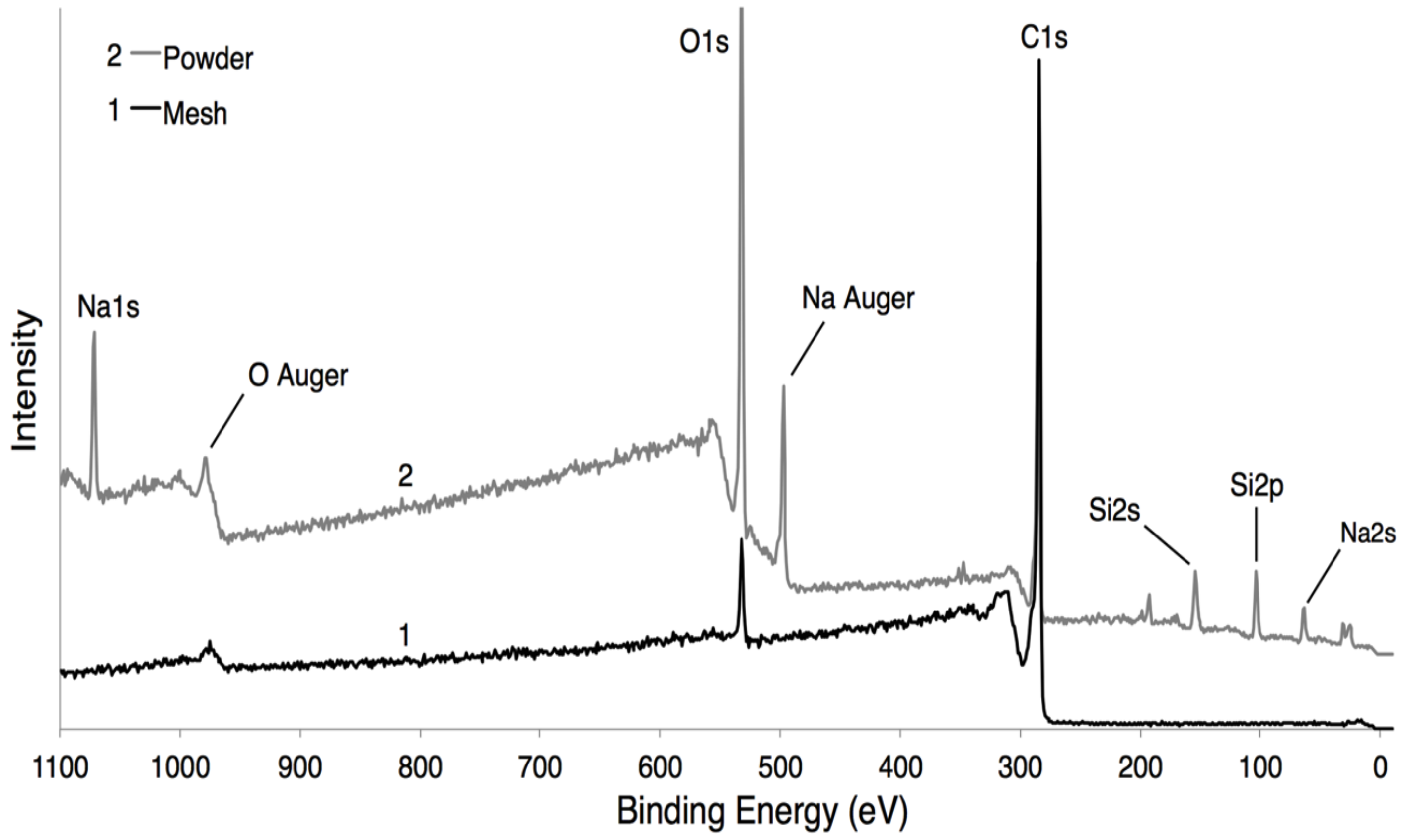
ZETA POTENTIAL



SURFACE OXYGEN CONTENT

	1 cycle			10 cycles	
	Pre-freeze	Post-thaw		Pre-freeze	Post-thaw
Sample	at.% O	at.% O	Sample	at.% O	at.% O
F-1	5.5 ± 0.4	5.8 ± 0.2	F-4	6.1 ± 0.2	6.0 ± 0.3
F-2	11.7 ± 0.4	11.5 ± 1.0	F-5	6.7 ± 0.7	5.5 ± 0.2
F-3	7.0 ± 0.6	6.6 ± 0.4	F-6	7.0 ± 0.0	6.4 ± 1.0
P-1	3.3 ± 0.5	2.8 ± 0.5	P-4	1.7 ± 0.2	1.7 ± 0.3
P-2	1.8 ± 0.2	1.3 ± 1.6	P-5	4.1 ± 0.2	4.9 ± 0.3
P-3	1.2 ± 0.8	0.6 ± 0.8	P-6	2.1 ± 0.2	2.4 ± 0.8

IMPURITIES



Discussion

- Average nanofluid recovery 50 to 75% of initial stock concentration
    - nanotubes can be redispersed after phase change cycling
    - Sharp initial drop in relative concentration may act as purification step

- Average particle size (PS) increased after cycling
    - Clusters of nanotubes not fully disentangled
    - Concentration only a broad diagnostic of stability
    - Stability is greater at smaller particle size

- Average zeta potential initially -48 mV
    - Indicative of good stability
    - Gradual increase to more positive values due to salt dissolution from glass containers

- XPS measurements show surface oxygen content were unchanged after freezing/thawing
    - Oxygen functionalities likely remain intact

Conclusions

- The freezing and thawing process causes reversible entanglement of f-MWCNTs since oxygen groups are preserved

- Variance in oxygen content on f-MWCNTs may explain concentration drop after the first cycle

- The use of borosilicate glass as a storage vessel for aqueous f-MWCNTs may cause a gradual loss of stability

- Aqueous f-MWCNT nanofluids are for viable long-term enhancement of water/ice phase change

Acknowledgements

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