

Summary of Interactions on Nano-Materials Projects

- University contributors



- Industrial collaborators



Objectives

- **Goal:**
 - **Work as a research consortium to solve a common set of questions regarding NPs used in CMP slurries**
- **Objectives:**
 - **Phase I**
 - **Procure “realistic” CMP slurries with representative NPs**
 - **Characterize physical properties & Toxicity of NPs**
 - **Phase II – Assess contribution of NPs relative to other additives in more complex CMP fluids & NPs in post-polishing fluids**
 - **Phase III – Work to characterize NPs in full-scale fabrication facilities using toxicity and analytical tools developed in Phases I/II**

CMP Procurement

- 4 “simple” CMP slurries developed with input from industry experts (Babu), industrial partners, and university researchers

Slurry ID	pH	NP Composition	NP size by SEM (nm)	NP size by DLS (nm)	NP Conc.	Zeta Potential at slurry pH
CMP1	pH 3.3 in acetate	Colloidal SiO ₂	37 ± 7	45	27 g Si/L	-21 mV
CMP2	pH 10.6 in KOH	Fumed SiO ₂	38 ± 14	184	50 g Si/L	-50 mV
CMP3	pH 4.0	CeO ₂	43 ± 16	185	9.6 g Ce/L	43 mV
CMP4	pH 4.2 in nitric acid	Al ₂ O ₃	85 ± 21	157	29 g Al/L	55 mV

- Samples prepared by Cabot Corp with minimal additives
- Samples shipped to researchers in early November 2013

Physical Characterization

- Wide range of methods applied
- Analyses were cross-validated by at least 2 university partners in most cases
- Methods cross-validation is good (TEM, DLS, sp ICP-MS)
- All primary NPs are < 100 nm; some aggregate in the slurry or at neutral pH
- Elemental composition of slurry & NPs show impurities
- Consortium is drafting a manuscript characterizing these CMP NPs – for future reference to minimize repeating characterization
- CMP NP samples can now be procured by other researchers with a simple agreement

Toxicity Trends

- Toxicity of CMP fluids in physiologically relevant fluids had low toxicity (IC50 > 1 mg/mL)
- No DNA damage up to 0.1 mg/mL of slurry
- Fumed silica slurry more toxic than colloidal silica slurry; consistent with literature
- 2 silica slurries have higher propensity to bind to lipid bilayers than other 2 slurries
- Some additives in slurries (K, Zn) themselves impart toxic responses in some cell lines
- All testing has been *in vivo* ; future work with daphnia or other organisms would be useful
- Slurry distribution to inhalation toxicologists is in progress & soon to aquatic toxicologist (zebrafish embryo)

Fate and Transport

- Si NPs aggregated more slowly than Ce or Al slurries in culture media and near neutral pH
- Different slurries exhibit unique propensities to be removed by on-site chemical precipitation
- III/V ions are capable of sorbing onto some NPs, which impacts NP properties and fate of III/V materials

Ongoing work

- Stability of CMP NPs in different culture media and water chemistries
- Toxicity of CMP NPs with different cell lines and whole organisms
- Distribution of CMP NPs to wastewater biomass
- Preparing journal paper(s)
- Distributing 4 CMP NPs to other research groups to learn more
- Perform statistical analysis on physical chemical and toxicity data from Phase I & outside collaborator data to find common features of potentially problematic properties of NPs from a ESH perspective

Phase II Ideas

(open for discussion)

- Use 4 slurries in pilot CMP polishing lines to characterize (physical and toxicity) what changes during polishing from a ESH perspective
- Look at toxicity of CMP slurries with and without NPs, relative to IC50 of other common CMP additives (corrosion inhibitors, surfactants, oxidants) & how their presence affects stability of NPs themselves in wastestreams
- Look at if these CMP NPs facilitate migration of III/V ions, and associated toxicity, in wastestreams

Phase III Ideas

(open for discussion)

- Obtain even more “realistic” CMP NPs for testing
- Work with industrial partners to apply characterization & toxicity methods, exchange confidential samples, etc at full-scale fab’s
- Sample across polishing tools and on-site waste treatment systems (if present)
- Sample in-plant air for CMP NPs
- Sample local sewage and WWTP liquid & biosolids to “track” CMP NPs

Final thoughts & discussion

- Thanks to everyone in the consortium for an engaging & collaborative project
- Open discussion about directions for consortium from industry members

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