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Tuning the Surface Chemistry of Nanomaterials: A Perspective on the Challenges and Opportunities

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Extended Abstract

Great strides have been made in the preparation of engineered nanomaterials. These materials can be designed with fanciful shapes, intricately controlled and tuned composition, and finely adjusted properties. Many of these materials have transitioned to a more widespread preparation and utilization as we seek to harness the properties of these nanoscale entities. Large quantities (e.g., ton scales) have been produced on an annual basis for a select number of nanomaterials, and many others are being scaled-up for widespread incorporation into products and/or processes to prepare enhanced products. Challenges do, however, remain in the preparation of these materials. While the properties of many of these materials remain relatively stable with their intended use, others can degrade by a number of means. This degradation can include the dissolution of material from the nanomaterial, unwanted (and often irreversible) adsorption of species onto their surfaces, or an induced aggregation of the nanomaterials through uncontrolled interactions. Chemistries have been prepared to control and tune the surface chemistries of nanomaterials, such as through zwitterionic species that attach to their surfaces or high molecular weight polymers that form a barrier at its surfaces (e.g., polyethylene glycol). These barriers have limitations in their uniformity over all of the surfaces of the nanomaterials with defects therein presenting access to species that can attack the surfaces, leading to the unwanted processes outlined above. Assessing the uniformity of the surface chemistry within these materials, and predicting their long-term stability is a challenge. Many analytical techniques are either insufficient in their ability to quantify these atomic-scale defects or not yet developed for widespread implementation in quality control for the preparation and tuning of the surface chemistry of engineered nanomaterials. A few of these techniques and their promise for the future assessment of the surface chemistry of engineered nanomaterials will be discussed in brief. Alternative techniques are needed.

Some techniques have been developed to assess the colloidal stability of engineered nanomaterials. These techniques include flocculation studies that expose colloidal materials to varying conditions, such as varying temperature, pH and related factors that seek to induce a colloidal instability to colloidal materials through access of specific chemical species (e.g., oxidants, etchants, precipitants) to the underlying surfaces of the nanomaterial. These techniques are simple as they can be implemented with chemical species and equipment that is readily found in the most laboratories. Additional techniques have been established that extend the insight of these techniques. Of particular interest is the ability to assess the uniformity of a population of engineered nanomaterials. Quickly assessing this uniformity is important, such that the techniques can be widely and readily implemented. The goal being to guide the user in refinement of their techniques for further improving the quality of the surface chemistry of their materials. Many techniques are sensitive to the “response” from the majority of species. Opportunities exist in the ability to better quantify the degree of uniformity of the surface chemistry within a population of engineered nanomaterials, to do so quickly, and to enable users to adjust their procedures for improving the quality of their products.