Chapter 21

Product Design Applied to Formulated Products:

A Course on Their Design and Development that Integrates Knowledge of Materials Chemistry, (Nano) Structure and Functional Properties

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ABSTRACT

Product development is a multi-faceted role that a growing number of engineers are tasked with. This represents a significant shift in career paths for those employed in the chemical and materials engineering disciplines, who typically were concerned with bulk commodity manufacturing. This paradigm shift requires the undergraduate curriculum to be adapted to prepare students for these new responsibilities. The authors present here on a product design capstone course developed for chemical engineering seniors at the University at Buffalo (UB), The State University of New York (SUNY). The course encompasses the following themes: a general framework for product design and development (identify customer needs, convert needs to specifications, create ideas/concepts, select concept, formulate/test/manufacture product; and (nano)structure-property relations that guide the search for smart/tunable/functional materials for contemporary needs and challenges. These two main themes are enriched with case studies of successful products. Students put the course material into practice by working through formulated product design projects that are drawn from real-world problems. The authors begin by presenting the course

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organization, teaching techniques, and assessment strategy. They then discuss examples of student work to show how students apply the course material to solve problems. Finally, they present an analysis of historical student performance in the course. The analysis seeks to identify correlation between related student deliverables, and also between the Product Design course and a prerequisite materials science and engineering course.

1. INTRODUCTION

Chemical and materials engineers have historically been concerned with the production of bulk commodity chemicals and materials. However, the increasing demand for value-added technologies/products in niche markets has placed an emphasis on product design (Hill, 2004). The types of products that chemical and materials engineers work in range from food stuffs such as food shortenings (Ghotra, Dyal, & Narine, 2002) and ice cream (Goff, 1997), to drinks such as champagne (Liger-Belair, Polidori, & Jeandet, 2008), to detergents, antifouling coatings (Kochkodan, Johnson, & Hilal, 2014), pharmaceutical delivery systems (Ansel, Allen, & Popovich, 1995), cosmetics (Schnittger & Moitreyee, 2007), plastics (Gordon Jr., 2003; Strong, 2006), paints (Tadros, 2010), and even nanostructured cleaning/preservation agents for artwork (Baglioni et al., 2014). Engineers also focus on the environmental footprint and benefit to society associated with new products and processes, a practice called "green" engineering (Allen & Shonnard, 2002; Anastas, Heine, & Williamson, 2001).

Today's markets and applications require products to be multifunctional in order to offer greater value to customers. Formulated (or structured) products are multi-component systems which have been designed to perform specific functions, often making use of enhanced properties borne by their nano-organized structures (Cussler & Moggridge, 2001). Some of these products are "tunable" to external stimuli, and so must be designed to undergo physical or chemical transformations during their use (Costa, Moggridge, & Saraiva, 2006). Colloids make up a class of materials which is ubiquitous in consumer products due to the offered range of properties and high degree of compatibility with green engineering practices (Evans & Wennerström, 1999). Some examples of useful products which derive their function from the colloidal (nano- to micrometer) scale include lightweight/high strength composites, hydrophobic surfaces for repelling water, drug delivery vehicles, polymer electrolytes, bio-sensors, and oil spill dispersants. Soft materials with self-assembly properties (e.g., block copolymers) have shown tremendous promise due to their ability to uniformly order/disperse/emulsify small components within fluids and polymer blends, allowing for "bottom-up" fabrication of products at otherwise inaccessible length-scales (Alexandridis & Lindman, 2000; Case & Alexandridis, 2003; Hamley, 2007; Spontak & Alexandridis, 1999).

Product design encompasses a family of processes to shuttle promising concepts to useful finished goods (Bröckel, Meier, & Wagner, 2007; Dieter & Schmidt, 2009; Otto & Wood, 2001; Seider, Seader, Lewin, & Widagdo, 2009). The design process has been heavily implemented in industry because it captures useful and creative ideas and promotes their objective evaluation as potential solutions to a problem (Ulrich & Eppinger, 2008). Some industries are even regulated on the basis of their design documentation and quality systems. Briefly, the major tenets of product design (and those which are emphasized in our course) include: identifying customer needs, translating the needs into measurable quantities (specifications), brainstorming/researching for product concepts, objectively and efficiently selecting those concepts, and then formulating, testing, and manufacturing of a product. A core competency for engineers engaged in product development is a working knowledge of chemistry and materials science

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