Chapter 26
Functional Polymeric Coatings: Synthesis, Properties, and Applications

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ABSTRACT

Functional polymeric coatings comprise a diverse array of organic/inorganic functional groups, properties, and applications. This chapter attempts to provide a comprehensive review on the science and engineering of functional polymer coatings for both the novice and experienced chemist/chemical engineer. Functional polymer coatings are coatings that are designed through careful selection of organic/inorganic functional groups and controlled synthesis on the substrate's surface. The design leads to changes in the surface properties (e.g., adhesion, wettability, corrosion resistance, wear resistance, anti-fouling, non-stick, and anti-scratch) of a particular substrate (metal, glass, wood, or plastic). Functional polymeric coatings represent the "next generation" of coatings. These coatings dynamically respond to their environment, as opposed to a static coating that is used as a simple barrier, or for decorative purposes. This review is divided into three sections: (1) functionalization of polymers, (2) polymer properties and surface analytical techniques, and (3) applications.

INTRODUCTION

Coatings have been around since the dawn of civilization, and they have helped shape man's development and history for millennia. Primitive man used natural materials to paint or mark areas that he inhabited. The ancient Egyptians, Greeks, and Romans used various natural materials to coat, decorate, or impregnate various fabrics, tombs, and vessels. Since World War II, advances in the variety and availability of chemicals and improved methods of applying such materials has led to the development of

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functional polymer coatings. In today's modern world, coatings are ubiquitous. In our daily lives, many objects, devices, and structures are coated with films or paints. Objects, structures, and devices such as pots, pans, tools, houses, bridges, automobiles, aircraft, televisions, mobile telephones, and computers are "coated materials."

These organic-polymeric functional coatings have been developed over the past several decades not only to impart decorative and/or protective properties, but also to add functionality to the coating. This functionalization can be applied to numerous surfaces with profound effects on a surface's morphology, properties, and eventual application. For example, by imparting functionality to a surface, researchers can selectively tune the properties of the film to meet a specific application or to allow for the investigation and understanding of physiological, biological, or biomimetic phenomena.

In contrast to functional coatings, static coatings, which include decorative and barrier coatings, do not possess the properties necessary to "sense and respond" to their environment, as shown in Figure 1. The coatings found in the aerospace industry are normally multi-layered coatings consisting of a pretreatment, a primer, and a topcoat layer. In the automotive industry, such coatings can be four to six different layers. Each layer provides a specific function to the overall performance of the coating. Adhesion between layers, barrier properties to corrosion and environmental stimuli, and decorative properties are typically observed for static, barrier, or decorative coatings.

A fundamental shift has occurred over the past few decades, and current coatings research focuses on tailoring a coating's ability to react to external stimuli. The term functional coatings now describes coating systems that possess not only the properties of a static coating, barrier and decorative, but the unique property of functionality. Functionality imparts specific properties to a coating that normally depends on the specific end-use or application desired. A comprehensive review of functional polymer coatings is provided by Wu and Baghdachi (2015). Several functional, or smart coatings, have been commercialized such as the anti-fogging polyester PET coating known under the trade name Visgard® (Munikata, Yamauchi, Hirono, T., Kodama, S.-I., & Matsuo, M, 2001; FSI Coating Technologies, 2015).

Brady (2007); Baghdachi, Perez, and Shah (2010); Kantheti, Narayan, and Raju (2015); Anastasiadis (2013); Cohen Stuart, et al. (2010), and Koberstein (2004) have published excellent reviews of "smart coatings." These reviews have provided guidelines on the important properties necessary to impart functionalization on a surface. These properties include (1) surface structure, (2) surface segregation, and (3) surface reorganization. In order to meet current coating industry requirements, researchers are focused on controlling the chemical surface composition on a molecular scale while controlling the morphology on the micrometer and nanometer scales.

Most reviews have focused on either the functionalization methods necessary to impart specific surface properties on a substrate and/or the applications associated with a specific surface treatment. This

Figure 1. Schematic diagram of static coating