Corrosion as a Nanostructure Synthesis Strategy

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In the most general sense corrosion reactions involve the conversion of one material form, structure, and/or arrangement into another. The connotation of corrosion is almost always in a negative sense (i.e., degradation of materials resulting in loss of properties and performance). However, because corrosion reactions involve energetically favorable product formation (oxidation in the chemical sense), they are potentially one of the most rapid, inexpensive, and technologically relevant methods of self-constructing new materials and structures.¹ They can result in the formation of a myriad of phase arrangements, ranging from nanoscale clusters, dispersions, and phases (including fibers, tubes, whiskers, and pores) to external layers, varying from nanometers to hundreds of micrometers thick.¹

The use of corrosion reactions as a synthesis approach goes back decades. One of the best known examples from the engineered materials field is the Lanxide process developed in the 1980s,² which used accelerated oxidation processing of molten metals to manufacture ceramic and metal matrix composites. Another well-known commercial example of corrosion-based synthesis routes to bulk composite materials is internal oxidation, which is used, for example, in Glidcop® Cu to form nanoscale dispersions of alumina to achieve strength while minimizing the impact on electrical properties.³ The most technologically important example of corrosion-based synthesis

is thermal oxidation of silicon to form silicon dioxide for semiconductor industry applications.⁴

In recent years there has been an explosion of interest in nanoscale materials. Although often not recognized as such, corrosion reactions are at the forefront of many nanosynthesis techniques. This is because even though the results of corrosion reactions are evident on a bulk macro scale, their mechanistic basis can be traced to atomic and nanoscale processes (e.g., Reference 5). Reports of nanoscale oxide whisker and fiber formation during oxidation (particularly when water vapor species are present) go back at least 50 years.⁶ Metal dusting phenomena, whereby severe corrosion of alloys can occur in high carbon activity gaseous environments, results in the formation of carbon nanotube and related nanostructured carbon species and potentially offers a low-cost synthesis route to these materials.^{7,8} High-temperature chlorination reactions of transition metal carbides are of great recent interest for energy storage applications due to the potential to controllably form nanoporous carbon structures, the carbide-derived carbon class of materials.⁹ Aqueous and electrochemical corrosion phenomena are also widely used to form nanostructured materials (particularly templates) by processes such as dealloying, anodization, and other forms of passive film manipulation.^{10–12} In all cases, the more widespread recognition of the basis of these synthesis routes in corrosion phenomena may accrue significant benefit and insight from the decades of studies available in the corrosion literature.

This topic highlights recent examples of the use of corrosion reactions

to synthesize nanoscale materials. In the following papers, a diverse range of both low- and high-temperature corrosion processes have been exploited to successfully synthesize unique nanoscale structures of scientific and technical interest. A common theme among these papers is that the basis to achieve a high degree of synthesis control of desired nanoscale features is grounded in the fundamental understanding of the corrosion processes employed.

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