The electrodeposition of high-strength nanocrystalline metals and alloys as a means to augment the performance of electrical conductors

A cost-effective process change makes it possible to greatly enhance the strength-to-weight of electrical conductors by the application of ultrafine-grained nanocrystalline metal to realize significant weight reductions in electrical wiring systems.

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Nanocrystalline materials

Most of the metals, alloys and many non-metallic materials that the industry is familiar with are comprised of grains (or crystals) that have agglomerated to form a solid polycrystalline material. In conventional engineering metals, these grains are typically on the order of tens of microns (1 micron = 10^{-6} meter = 10^{3} nanometer) in diameter. Nanocrystalline materials, however, are composed of much finer grains, with diameters in the nanometer range (1 nm = 10^{-9} m). As a general guideline, a material with an average grain size (diameter) of less than 100 nm can be considered nanocrystalline[1]. Fig. 1 displays scanning electron microscopy (SEM) and transmission electron microscopy (TEM) micrographs of conventional coarse-grained and ultrafine-grained nano-crystalline materials, respectively.

Numerous methods exist for the synthesis of nanocrystalline materials. Some processes involve physical or chemical vapor deposition, rapid solidification, mechanical attrition, and/or electrodeposition. Synthesis via electrodeposition is of particular interest because this is a mature, well-established technology that is relatively robust and inherently inexpensive. Electrodeposition offers many advantages over other processing techniques, specifically: the ability to choose from a large range of available pure metals, metal alloys and metal-matrix composites (see Table 1); a high-degree of processing flexibility in terms of size, thickness and shape; high production rates; low initial capital investment relative to other nanomaterial synthesis methods; and a relatively simple process drop-in to existing electroplating lines[2]. The process of nanocrystalline electrodeposition has been successfully implemented in the nuclear, sporting goods and metal finishing industries. For example, elec-

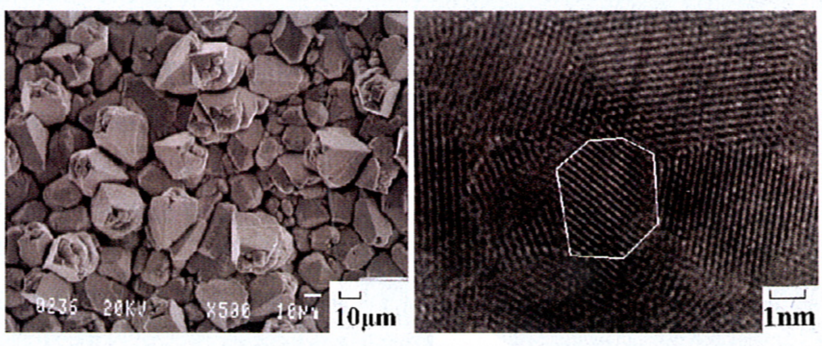

Fig. 1. SEM and TEM micrographs of coarse-grained (left) and ultrafine-grained nanocrystalline materials.

Pure Metals	Ni, Fe, Cu, Co, Pd, Au, Ag
Metal Alloys	Ni-Fe, Ni-P, Co-P, Co-W, Zn-Ni, Ni-Co
Composite Particles (Added to Metal Matrix)	Al_2O_3, SiC, Diamond, Graphite, BN

Table 1. Examples of nanocrystalline materials produced via electrodeposition.