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Nanodiamond dispersions in nanostructured metals

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A microstructure refined to the nanometer scale originates mechanical property improvements [1]. However ultra-fine grain metals present low thermal stability [1, 2], requiring the presence of particle dispersions to delay coarsening by grain boundary pinning. Nanoscale dispersions of diamond or graphite offer therefore thermal stability potential, combined with high hardness [1-6] and thermal conductivity for diamond [1], and self-lubricating properties in the case of graphite [6]. Copper-diamond (Cu-nD) and copper-graphite (Cu-G), nickel-diamond (Ni-nD) and nickel-graphite (Ni-G), as well as tungsten-diamond (W-nD) and tungsten-graphite (W-G) nanostructured composites have been produced by mechanical synthesis and subsequent heat-treatments. Fundamental challenges involve bonding carbon phases to the chosen matrices: copper exhibits an intrinsically difficult bonding with carbon; while tungsten is a strong carbide former; with Ni exhibiting intermediate characteristics. In addition, carbon phases are prone to amorphization by high-energy milling. Transmission electron microscopy (TEM) observations showed homogeneous particle distributions and intimate bonding between the metallic matrix and the carbon phases. Ring diffraction patterns of the chemically extracted carbon phases demonstrated that nanodiamond milled with Cu preserved crystallinity (Figure 1), while an essentially amorphous nature could be inferred for graphite. Systematic variation of the processing parameters enabled to minimize carbide formation with Ni and W matrices. Heat-treatment of the nanostructured of Ni-nD composites induced the transformation of nanodiamond into onion-like carbons (OLC) inside the Ni nanostructured matrix (Figure 2). Hardening mechanisms and the load transfer ability to the reinforcement particles, as well as thermal stability, have been evaluated through microhardness tests.

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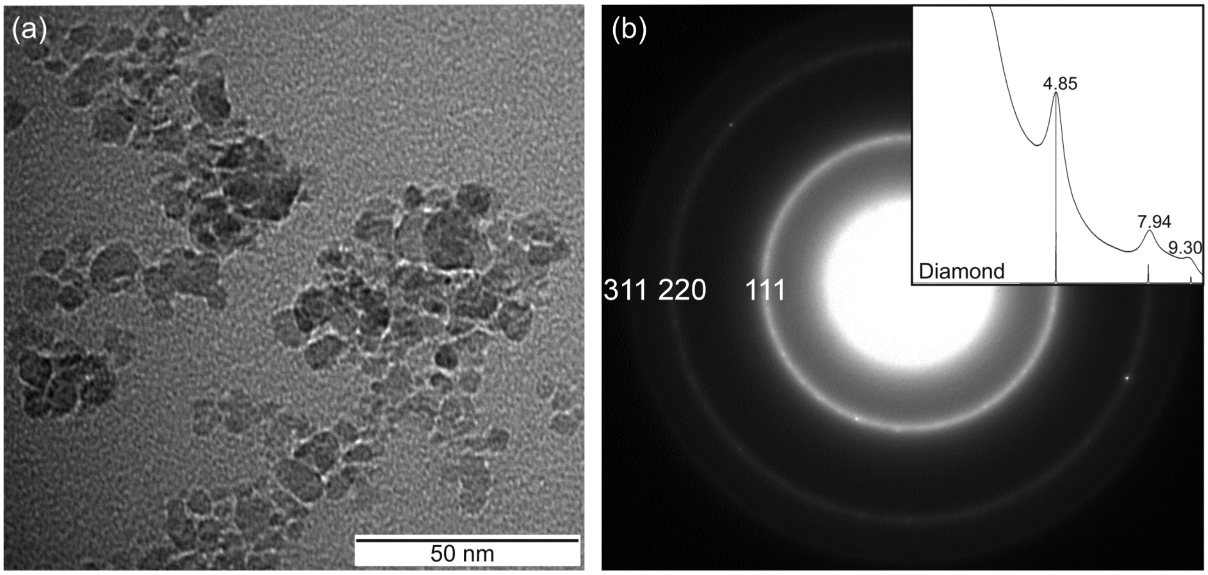

Figure 1. (a) Bright-field TEM image of the nD chemically extracted from Cu-nD composites (b) Ring diffraction pattern with integrated radial profile (diamond simulation included with legend in nm^{-1}).

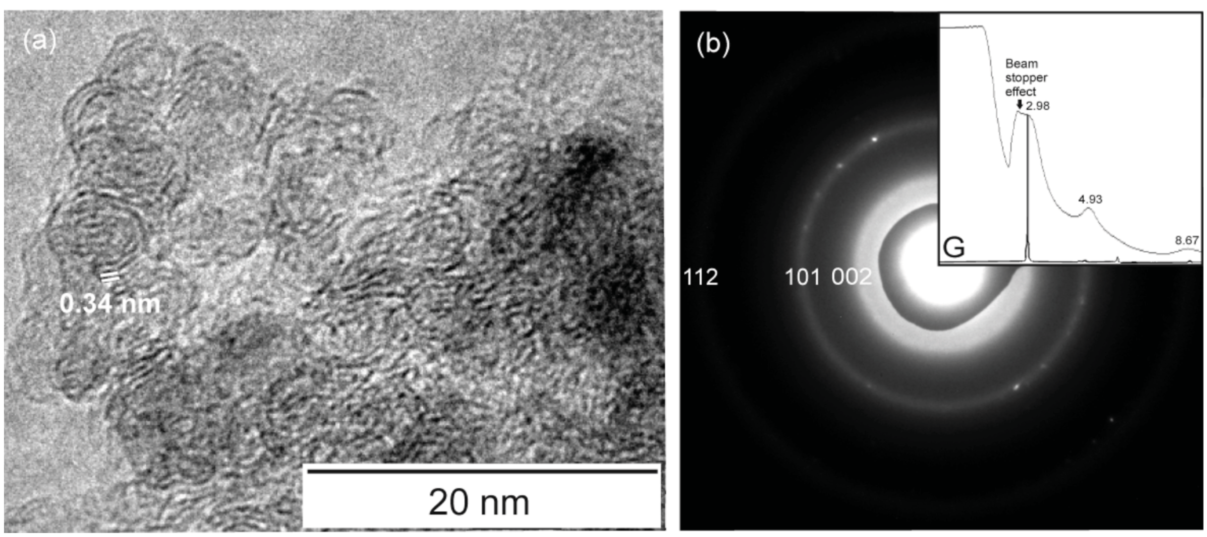

Figure 2. (a) Bright-field TEM image of the material chemically extracted from heat-teatred Ni-nD composites heat-treated at 1673 K. (b) Ring diffraction pattern with integrated radial profile (graphite simulation included with legend in nm^{-1}).

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