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Synthesis and Characterization of Low-Cost Superhard Transition-Metal Borides

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The increasing demand for high-performance cutting and forming tools, along with the shortcomings of traditional tool materials such as diamond (unable to cut ferrous materials), cubic boron nitride (expensive) and tungsten carbide (relatively-low hardness), has motivated the search for new superhard materials for these applications. This has led us to a new class of superhard materials, dense refractory transition-metal borides, which promise to address some of the existing problems of conventional superhard materials. For example, we have synthesized rhenium diboride (ReB_2) using arc melting at ambient pressure. This superhard material has demonstrated an excellent electrical conductivity and superior mechanical properties, including a Vickers hardness of 48.0 GPa (under an applied load of 0.49 N). To further increase the hardness and lower the materials costs, we have begun exploring high boron content metal borides including tungsten tetraboride (WB_4). We have synthesized WB_4 by arc melting and studied its hardness and high-pressure behavior. With a similar Vickers hardness (43.3 GPa under a load of 0.49 N) and bulk modulus (326-339 GPa) to ReB_2, WB_4 offers a lower cost alternative and has the potential to be used in cutting tools. To further enhance the hardness of this superhard metal, we have created the binary and ternary solid solutions of WB_4 with Cr, Mn and Ta, the results of which show a hardness increase of up to 20 percent. As with other metals, these metallic borides can be readily cut and shaped using electric discharge machining (EDM).