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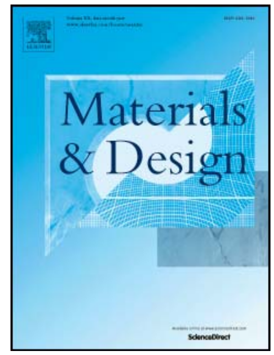

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Mechanical properties of a diamond-copper composite with high thermal conductivity

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Abstract. Using pressureless infiltration of copper into a bed of coarse (180 μm) diamond particles pre-coated with tungsten, a composite with a thermal conductivity of 720 W/(m K) was prepared. The bending strength and compression strength of the composite were measured as 380 MPa. As measured by sound velocity, the Young's modulus of the composite was 310 GPa. Model calculations of the thermal conductivity, the strength and elastic constants of the copper-diamond composite were carried out, depending on the size and volume fraction of filler particles. The coincidence of the values of bending strength and compressive strength and the relatively high deformation at failure (a few percent) characterize the fabricated diamond-copper composite as ductile. The properties of the composite are compared to the known analogues – metal matrix composites with a high thermal conductivity having a high content of filler particles (~ 60 vol.%). In strength and ductility our composite is superior to diamond-metal composites with a coarse filler; in thermal conductivity it surpasses composites of SiC-Al, W-Cu and WC-Cu, and dispersion-strengthened copper.

Keywords: metal matrix composite, thermal conductivity, strength, elastic constants

1. Introduction

Metal matrix composites (MMCs) with a high content of ceramic filler particles are a fairly specific class of materials. Simply to ensure low residual porosity in the manufacture of MMCs with a high ceramic content is a technological problem – see, for example, [1]. In this study, composites of Al_2O_3 particles of ≈ 60 μm in a copper matrix, with an Al_2O_3 content of 30 to 60% vol. were obtained; the porosity of the composites was 1–3%. Although the modulus and hardness increase monotonically with ceramic content, if the filler content increases above about 25%, MMC strength and toughness usually reduce so that such materials are not considered as constructional. Thus, commercially available conventional composites for constructional purposes, with matrices of aluminum-magnesium alloys, contain 10–25% vol. particulate fillers of Al_2O_3 or SiC and have a tensile strength σ_t = 240–740 MPa, elongation at failure ε = 0.3–7.5%, and modulus of elasticity E = 50–120 GPa [2]. Relatively recently, it was shown that composites with a high content of ceramic particles in a metal matrix can have good mechanical properties. For composites made with B_4C or Al_2O_3 particles ranging in size from 15 to 60 μm, with a binder of pure aluminum or Al-Cu alloys, the authors demonstrated relatively high tensile strength (from 130 to 440 MPa) and ductility (elongation at failure ε =1–4.5%) at a volume fraction of filler θ_f of 45–60% [3]. Another area of development in the field of MMCs is the use of new substances as fillers with a high content. For example, in [4] a composite was obtained with particles of the complex metal alloy Al_3Mg_2 of approximately 40 μm in an aluminum matrix; as θ_f was increased from 20 to 80%, the yield stress σ_y increased from 230 to 590 MPa and the strain at failure ε reduced to an acceptable value (from 46 to 1.5%). When θ_f = 60%, the composite had the strength σ_y = 450 MPa and the ductility ε = 2.0%.

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