# Use of mechanical alloying for production of MMC with nanodiamond reinforcements

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MMC were produced by mechanical alloying of the components to obtain composite granules followed by their consolidation into a compact material. Commercially pure copper and nickel, as well as aluminium alloys, were used for the matrix. The content of the ND fraction was varied from 5 up to 40 vol.%. Mechanical alloying was performed in planetary mills with balls and quasicylindrical milling bodies as process tools.

The composite materials with an increased concentration of nanodiamond reinforcing particles feature an increased air oxidation after a small treatment time. This effect is found for all matrix materials studied, i.e., for aluminium, nickel, and copper. The emergence of cuprous oxide in granules with ND content greater than 20% is confirmed by the X-ray diffraction method. However, increased oxidation is observed only for clusters of crushed, separate, and partially matrix-bound ND particles. After a prolonged treatment in a planetary mill, which leads to an even distribution of nanoparticles in the matrix and to the absence of free particles on the surface of granules, the effect is much smaller or almost absent. Conditions are determined for the effect of the treatment regimes on the uniform distribution of reinforcing ND particles in the copper matrix for different milling tools.

It is known that copper oxides, especially copper(I) oxide, are the most efficient materials for protection from biofouling. That is why formation of copper oxides (including the large volume fraction of copper(I) oxide) on the surface of the copper matrix composites with large ND volume fraction suggests them to be suitable for biofouling protection systems of marine facilities. This material can be used in the form of granules after mechanical alloying, as a component of paints, lacquers, and polymer coatings; as a component of bulky composite materials (e.g., additives to concretes); and, after compaction, for articles operated in water but carrying no large loads. Three specimens were kept for 100 days in marine water during the summer season to determine the efficiency of using the developed material in biofouling protection systems of marine falicities: (1) the control specimen without protection; (2) a plate from chlorinated polyvinyl chloride resin CPVC+40% copper(I) oxide composite coated with standard antifouling paint; and (3) a specimen from the developed Cu+25%ND composite. The study shows the absence of biofouling on specimens 2 and 3; on the control specimen, the biofouling is 0.52 g/cm$^2$ per year.