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STUDY OF THE PHASE COMPOSITION OF PRODUCTS OF MECHANOCHEMICAL INTERACTION IN Ta+C SYSTEMS

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Abstract

At present, one of the most important tasks of modern materials science is the creation of materials for operation in extreme conditions at high temperatures and stresses, under the influence of aggressive media, etc. Tantalum carbide is such a refractory compound, which is widely used in industry, in hard alloys, carbide steels, as a material for aviation, rocket technology, a material for electrical and radio engineering purposes, in particular as part of eutectic heat-resistant alloys.

Keywords: carbide, tantalum, heat - resistant alloy, mechanochemical interaction, mechanoactivation.

1 Introduction

One of the most important tasks of modern materials science is the creation of materials for operation in extreme conditions at high temperatures and stresses, under the influence of aggressive media, etc. In solving these problems, a significant role belongs to the use of refractory metals and their compounds - borides, carbides, nitrides and silicides, which, along with high hardness and refractoriness, have heat resistance and heat resistance, specific physical and chemical properties. These compounds largely determine the properties of various alloys, ranging from carbon and alloy steels to hard alloys used for metalworking and rock drilling. Among carbides of refractory metals , tantalum carbide has high performance properties , which makes it potentially suitable for solving many problems of modern materials science: as components and alloying additives of hard alloys, composite materials of various profiles, for protective coatings, surface and volume modification of metal alloys and materials, etc.d.

Mechanochemistry is a science that develops on the verge of chemistry and mechanics: it is also closely related to other areas of science and technology, physics, especially solidstate physics, biophysics, physical chemistry, polymer technology, chemistry and technology of inorganic substances, biochemistry, molecular biology, bionics. Mechanochemistry, selecting and reworking certain facts and regularities taken from all these fields of science, in turn puts forward its own regularities and conclusions that contribute to the development and enrichment of the parent sciences. In the most general definition, mechanochemistry can be called a science that studies the mutual transformations of mechanical and chemical energy occurring in bodies. But the creation of a single, comprehensive representation, comprehensively reflecting all aspects of the mechanochemical process, should be based on knowledge of the complex structure of the object under study, which is determined by the number of levels of supramolecular organization. The mechanochemical phenomenon includes two main components: mechanochemical, which determines the transformation of mechanical energy into chemical, and chemomechanical, which is the release of mechanical energy due to chemical reactions.

2.Methods

Tantalum carbide can be obtained by one of the following methods [1].

1. Reduction of tantalum oxide with carbon followed by the formation of carbide.

The reduction of $Ta_2 O_5$ and the subsequent formation of tantalum carbide is carried out at temperatures of 1400-1600°C in a hydrogen environment or in a vacuum. Soot is the source of carbon.

2. Direct saturation of tantalum with carbon.

In this case, the technology for obtaining tantalum carbide is similar to the method presented above, only in this method the oxide is replaced by metallic tantalum.

A variation of this method is the production of tantalum carbide in a graphite crucible containing tantalum, carbon and a melt of aluminum or other iron group metals instead of aluminum at temperatures up to 2000°C. The resulting product is treated with an acid to dissolve the aluminum or iron by-product carbides formed.

3. Deposition from the gas phase.

The method is based on the process of reduction of tantalum pentachloride at the surface of a tungsten or carbon filament to tantalum, which interacts with a hydrocarbon medium at temperatures from 2000°C to 2930°C.

4. Recovery melting of tantalum-containing slags.

The reduction and carbidization of tantalum occurs due to the addition of carbon to the slag with a large excess and in the presence of iron. The resulting carbide is isolated chemically.

On an industrial scale, tantalum carbide is mainly produced by carbothermal reduction of Ta_2O_5 with carbon due to the low cost of raw materials. It has been reported that tantalum carbides can be obtained by heating Ta_2O_5 at high temperature in high vacuum and higher temperatures for a long time [2]. The fast and complete reaction is due to the high temperature treatment of TaC, so it also causes coarsening of the carbide grains. Reducing the size of the carbide usually gives a significant improvement in mechanical properties [3]. The strength of ceramics can be significantly increased without sacrificing hardness by reducing the grain size [4].

The change in the temperature of the mechanoreactor t_{mr} is shown depending on the duration of mechanoactivation τ_{MA} of tantalum powder in the presence of soot and without it (Figure 1).

Mathematical processing of the results of the study of the process of structure formation of heterocomposite materials and coatings, using the Newton interpolation formula and the Lagrange method, taking into account rheological parameters, it is proposed to use heterocomposites intended for both large-sized and complex-configuration technological equipment, and sheet structural materials.

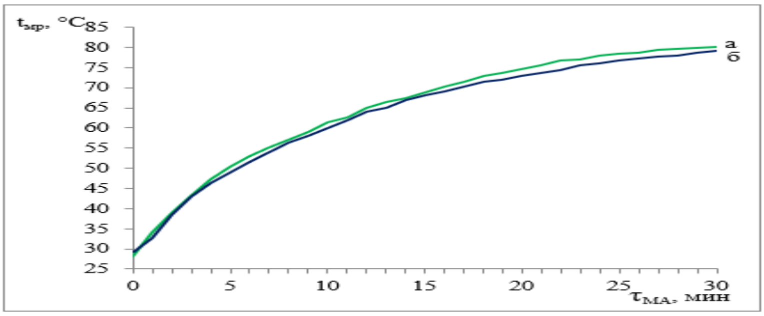

Figure 1. The temperature of the mechanoreactor t_{mr} depending on the duration of MA τ_{MA} : a - a mixture of "Ta + C", b - tantalum powder. Grinding bodies made of steel ШХ-15

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As can be seen, the temperature of the mechanoreactor during MA of the “Ta + C” system is slightly lower than when processing tantalum powder without carbon addition, which reflects a minimal increase in the temperature balance due to the imposition of the thermal effect from the implementation of mechanochemical reactions.

The result of X-ray phase analysis of the powder product obtained as a result of 5 minutes of MA of the Ta + C mixture using steel grinding bodies is shown in figure 2. As can be seen, only reflections of pure tantalum are recorded in the diffraction pattern of the mechanochemical processing products. As a result of the considered time interval, tantalum carbide is practically not registered.

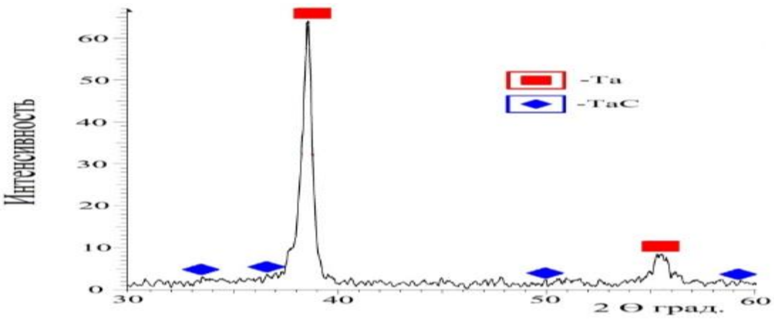

Figure 2. Powder diffraction pattern after MA mixture " Ta + C" for 5 min; Grinding bodies made of steel ШХ-15

Obviously, 5 minutes of mechanoactivation of the metal-carbon mixture is not enough to start mechanochemical reactions in the volume of the processed mixture of initial components. The content of tantalum carbide in the products of mechanical activation does not exceed 3%.

The morphology of powder particles after MA of the Ta + C mixture for 5 min is shown (Figure 3).

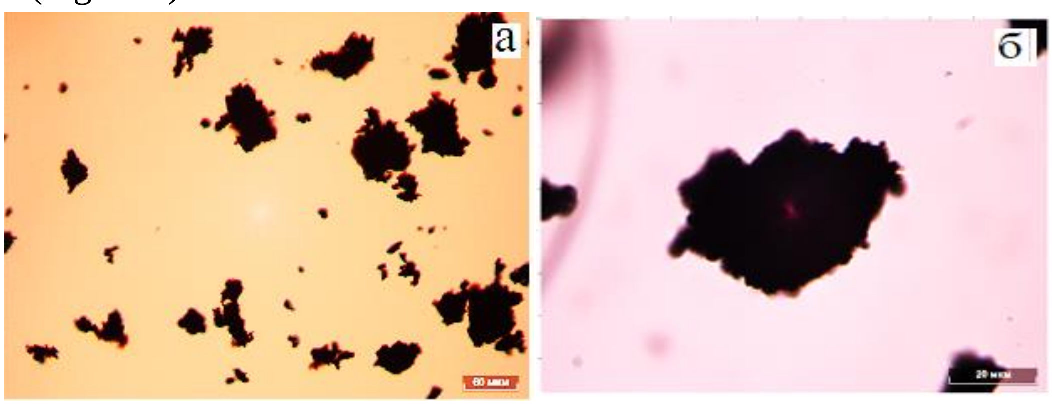

Figure 3. Morphology of powder particles after MA of the “Ta + C” mixture for 5 min, with magnifications: a – ×200 ; b – ×1000

As in the case of microstructural analysis of powders, after mechanochemical treatment of the "Ta + C " system, the process of agglomeration of fine particles is observed. This is confirmed by the results of a study of the fractional composition of powders, carried out on a laser particle analyzer. As can be seen, a significant reduction in powder It is observed already after 5 minutes of vibration treatment. The maximum particle size of the powder decreased by half - from 30 to 15 microns.

3. Conclusions

It has been established that long-term vibration treatment of the Ta + C mixture leads to the formation of a powder composition, including tantalum, tantalum nitride, tantalum carbide, and steel ball grinding products.

It is shown that the vibration treatment of the Ta + C mixture does not make it possible to obtain a high-quality final product with a high TaC content due to the need for a significant increase in the mechanical activation time and its contamination with grinding body wear products.

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