CONSOLIDATION AND STRUCTURE FORMATION DURING THE SINTERING OF COMPOSITES BASED ON NITRIDES OF TRANSITION METALS OF GROUPS IV-V. IV. SINTERING OF COMPOSITE MATERIALS OF (VN, TAN) – NI SYSTEM

F. F. Egorov and V. E. Matsera

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A study is made of the sintering of (VN, TaN) – Ni composites in argon under isothermal and nonisothermal conditions. It is shown that the sintering of these materials is characterized by a reaction between the components, which is accompanied by the release of nitrogen from the nitrides and the formation of solid solutions and intermetallides based on nickel. These processes affect the rate and sign of the consolidation process. It is established that nitrides of vanadium and tantalum are sintered with nickel considerably more rapidly and at a lower temperature than nitrides of group-IV transition metals. Isothermal sintering leads to a slowing of consolidation compared to nonisothermal sintering, which can be attributed to the release of nitrogen from the nitrides and its localization in closed pores. The sintering is accompanied by an increase in the volume content of the metallic binder and a change in its phase composition (intermetallides of nickel and nickel-based solid solutions form). TaN – Ni materials are characterized by a solid phase with very fine grains (∼1 µm).

Keywords: isothermal and nonisothermal sintering, reaction of the components, consolidation, solid solution, intermetallide, phase composition, structure.

Materials based on nitrides VN and TaN and having a nickel binder can be used as structural materials in certain areas of engineering. The properties of sintered cermets are determined by their phase composition and by the structure forming during the sintering. We do not know of any publications that have been devoted to studying sintering and structure formation in quasi-binary systems of metal-like nitrides of group V transition metals that include vanadium and tantalum with nickel.

The goal of this investigation is to study the processes which take place during consolidation and formation of the structure of materials in the systems (VN, TaN) – Ni as a function of sintering temperature and time. The methods used to study features of the consolidation of the compacts (initial diameter 8 mm, initial height 8-12 mm) and check the composition and structure of the specimens corresponded to the methods described in [1].

We studied consolidation and structure formation in the systems VN – Ni and TaN – Ni during sintering in purified argon (excess pressure 0.35-10^5 Pa) under isothermal and non-isothermal (continuous uniform heating at a rate of 20 deg/min) conditions. The study was performed using powders of the nitrides VN_{0.861} and TaN_{0.884}, as well as powders of grade-PNE electrolytic nickel (GOST 9722-79) with a purity of 99.3 mass%. The content* of nickel in these composites was 30 and 40%.

Figure 1 shows curves describing the consolidation of VN – Ni and TaN – Ni specimens in relation to temperature in the case of continuous uniform heating. It is apparent that significant consolidation begins in these systems at 1200°C; this temperature is 260°C lower than in the system (VN, TaN) – Cr [2] and 400 and 200°C lower

*Here and below (unless otherwise noted), the contents of the components are expressed in vol.%.

than in the systems (TiN, ZrN) – Ni [3]. The rate of consolidation increases markedly at the temperature at which the liquid phase appears. However, a further increase to a point 100-150°C above that temperature causes the rate of consolidation to decrease sharply and even drop to zero. As in all of the systems studied previously [1-3], such behavior is due to the reaction between the components. That reaction is accompanied by the release of nitrogen from the nitrides and the formation of an alloy.

It is known [4] that the slowing of consolidation in a binary powder system may be due to processes which involve the formation of an alloy. In particular, it may be due to the formation of solid solutions and intermetallides. X-ray phase analysis (XPA) confirms that sintered specimens of the composition VN + Ni and TaN + Ni contain solid solutions of vanadium and tantalum in nickel. The specimens also contain the intermetallides Ni₃V, Ni₂V, Ni₃Ta, Ni₂Ta, and NiTa. However, according to XPA data, solid solutions and intermetallides begin to be formed in the specimens considerably before the rate of consolidation begins to decrease. In connection with this, we will assume that the mass transfer which is caused by the formation of an alloy is likely to occur in the given case and that it will be of the same sign as the mass transfer which takes place as a result of capillary forces. Thus, the appearance of a liquid phase will stimulate rather than inhibit consolidation, despite the accompanying sharp increase in diffusion and the rate of alloy formation. The slowing of consolidation and the increase seen in the size of the specimens in some cases during sintering above 1500°C should be linked with the liberation of gases during decomposition of the nitrides and localization of those gases inside the specimen, since it is during this period that mainly closed porosity is created within its structure.

Comparing the character of the consolidation which occurs during the sintering of nitrides of transition metals of groups IV and V with nickel, we can conclude that the nitrides of the group V metals sinter considerably more rapidly and at lower temperatures. However, due to the lower thermodynamic stability of the nitrides of group V metals, the same nitrides also begin to react with nickel at lower temperatures. This has a positive effect on the consolidation of the specimens at high temperatures during liquid-phase sintering.

Fig. 1. Temperature dependence of specimen dimensions during uniform continuous heating in argon at a rate of 20 deg/min; specimen composition: TaN – 30% Ni (1); VN – 30% Ni (2); VN – 40% Ni (3).

Fig. 2. Change in porosity in relation to isothermal holding temperature and time during the sintering of composites of the composition VN – 30% Ni (1, 1') and TaN – 30% Ni (2, 2').