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SHS system "Ti-Co-N": relation between the combustion process and the phase diagram

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Abstract

The self-propagating high-temperature synthesis (SHS) of the Ti – Co – N system is studied, and the relation between the combustion parameters and the phase diagram is established.

The goal of the work is to analyze the variations of different initial parameters and the relation of the phase composition of the combustion product with the processes occurring in the combustion wave and with the phase diagram of the system. SHS processes are found to occur only inside the "L-S" solid-liquid melt.

Introduction

This work is devoted to studying the mechanism of phase and structure formation of the SHS system: "Ti-Co-nitrogen" in the combustion wave. The formation of the final product was shown to occur through an intermediate stage of the formation of Me_2N polynitride or a solid solution of nitrogen in the metal, which in the afterburning zone were nitrided to nitride, the composition of which is close to stoichiometric MeN. The expansion of the class of synthesized nitride compounds will allow materials to be obtained with new unique properties.

This reactive medium is open, irreversible, nonlinear, or dissipative, since nitrogen continuously enters it, the product continuously exits, and energy enters and exits. Each act of SHS is a kind of sensor that provides information about a reactive medium, characterizing its state. The chemical reaction zones of the system are a solid-liquid melt corresponding to the "L-S" melt on the phase diagram of the system, into which the active reagent, gaseous nitrogen, continuously flows [1-7]. All the obtained combustion parameters of this system under different initial conditions characterize the behavior of a high-temperature reactive solid-liquid medium.

EXPERIMENTAL

SHS was conducted in a constant pressure reactor.

The relative density of the samples varied from 0.22 to 0.38.

The initial composition changed in the following ratio: Co/Ti% wt. within 5/50.

The diameter of the samples was 20 mm; the initial weight of the sample was 16 grams.

The final products were investigated using X-ray diffraction analysis.

The following system parameters were determined:

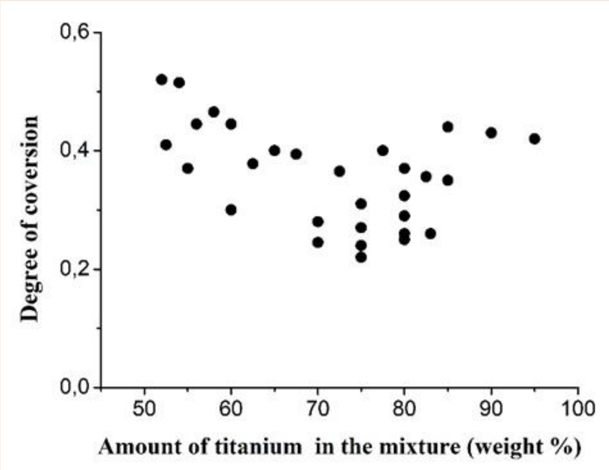
the absorbed amount of nitrogen (electronic balance; the measurement method is the difference in weight before and after combustion of the sample with an accuracy of ± 0.005);

maximum combustion temperature (thermocouple method with recording on an analog digital converter);

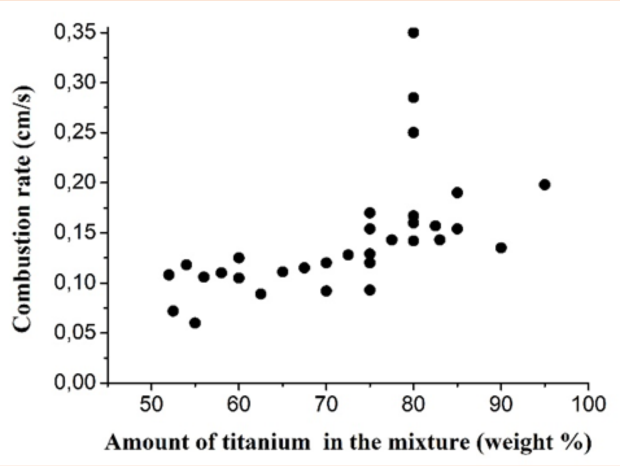
combustion rate (a method based on measuring the time of a combustion wave propagation in a vertical direction between the sensors.

Tungsten-rhenium thermocouples were used as the sensors.

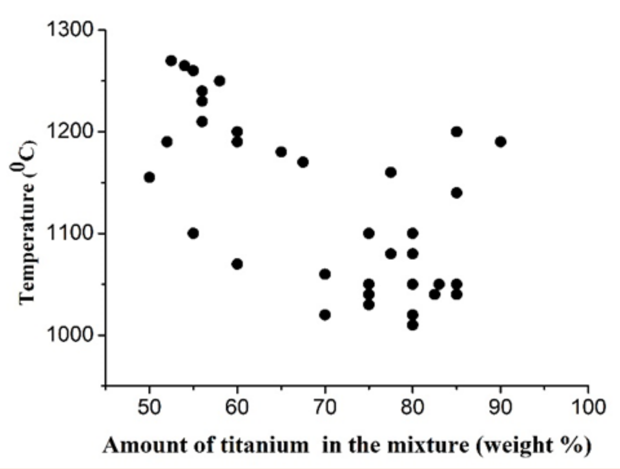
RESULTS



The cloud of data on the degree of conversion versus the initial ratio of starting titanium and cobalt.



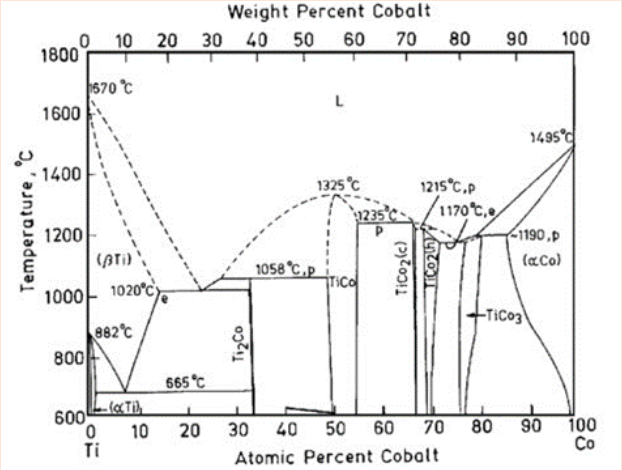
The combustion rate versus the ratio of the starting components.



The maximum combustion temperature versus the ratio of the starting components.

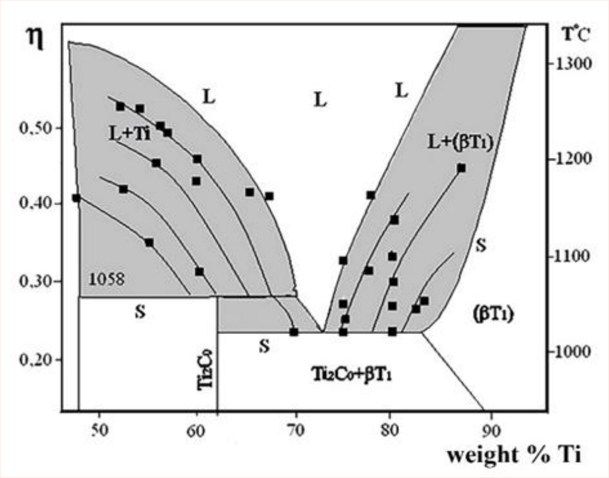
All the figures do not show a logical dependence.

RESULTS



Phase diagram of the "titanium - cobalt" system.

This section of the phase diagram was combined with the experimentally obtained values of conversion degree and temperatures. **Figure shows that all the obtained values are located in the "L-S" area of the phase diagram.**



Part of the "titanium - cobalt" phase diagram combined with the experimental values of conversion degree and temperature.

RESULTS

The analysis figures shows that **combustion occurred only in the case when the composition and the temperature corresponded to the "L-S" medium**. The same experimental points in the same coordinate space can be combined into other trajectories with a unifying invariant, which is the atomic ratio of nitrogen and titanium in Ti_pN_e nitrides.

X-ray diffraction analysis of the synthesis products showed that in the final product almost all titanium was connected with nitrogen TiN_{1-x}, where x is the mass fraction of titanium in the starting mixture, and the matrix was a solution of titanium in nitrogen. Based on the XRD, it was concluded that during the combustion of the "Ti-Co-N" system, the final product formed through intermediate nitrides, which decomposed with a further increase in temperature.

Heating a powder of one metal to a temperature above solidus leads to the formation of a pure melt, which is an obstacle to the entrance of nitrogen into the reaction. Heating two different metals above solidus temperature leads to the formation of an equilibrium suspension consisting of the particles of solid solutions or compounds. In such a multi-density medium a vortex motion is easily formed at high temperatures, entrains gaseous nitrogen and delivers it to the reaction.

CONCLUSION

The analysis of the variations of different initial parameters established that SHS processes in the “Ti–Co–N” system occurred only inside the solid-liquid melt of the “L-S” phase diagram.

REFERENCES

[1] S.Dehlouz, A.Alhussein, F.Lacroix et al. ,Self-combustion of Ti-C and Ti-Al Powder Mixture in a Nitrogen Atmosphere: Product Application as Reinforcement in Metal Matrix Composites. J. of Materi Eng and Perform 29, 1984–1994 (2020). https://doi.org/10.1007/s11665-020-04709-w

[2] G.S.Oniashvili, Z.G.Aslamazashvili, G.V.Zakharov,. et al., SHS of fine-grained ceramics containing carbides, nitrides, and borides. Int. J Self-Propag. High-Temp. Synth. 22, 185–188 (2013). https://doi.org/10.3103/S106138621304002X

[3] A.S. Mukasyan, and I.P.Borovinskaya, Structure Formation in SHS Nitrides, Int. J. SHS, 1992, vol. 1, no. 1, pp. 55–63.

[4] L.G.Raskolenko, A.Y. Gerul’skii, Compounds WAl4, WAl3, W3Al7, and WAl2 and Al-W-N combustion products. Inorg Mater 44, 30–39 (2008). https://doi.org/10.1134/S0020168508010056

[5] Y.M.Maksimov, O.K. Lepakova, L.G. Raskolenko, Combustion mechanism of a titanium-boron system with the use of quenching of the reaction front. Combust Explos Shock Waves 24, 43–48 (1988). https://doi.org/10.1007/BF00749069

[6] N.V.Kruglova, L.G. Raskolenko, and Yu.M. Maksimov, Self-propagating High-Temperature Synthesis of Three-Component Systems Based on Titanium and Group III, VI, and VIII Metals with Nitrogen, Izv. Vyssh. Uchebn. Zaved., Tsvetn. Metall., 2002, no. 2, pp. 56–59.

[7] L.G. Raskolenko, O.A. Shkoda, The Dynamic Structure Plotting During Experimental Research Into The Behavior of Systems With Complex Organization, Eurasian Physical Technical Journal. Volume 7, No. 2(14), 2010, pp. 49 – 52

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