Compatibility of the non-metallic structure modifiers nanoscale particles with common filler alloys of aluminum welding

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Objectives

The great demand for light aluminum constructions has spurred materials scientists to create new light-alloy materials based on aluminum, as well as composite materials based on them. The creation of new aluminum alloys and composites based materials sharply raises the demands of ensuring their reliable connection in the structure. At the same time, classical welding filler alloys based on Al-Mg and Al-Si alloying systems no longer provide the required level of mechanical properties of the weld metal, relative either to the characteristics of new alloys and composite materials. Welding of the latest high-strength aluminum alloys, as well as aluminum-matrix composites based on them, today has many difficulties that need to be solved. The main problem of welding new multicomponent aluminum alloys is the insufficient level of properties of industrial welding wires, as well as the burnout of alloying elements during welding, both from the body of the part and from the filler material.

The work discovers the features of application promising nanoscale non-metallic microstructure modifiers (particles TiC, WC, SiC, TiB_2) of a weld in aluminum alloys welding process. The particles applicability was assessed from the standpoint of thermodynamic stability into melts of industrial welding alloys of Al-Mg and Al-Si alloying systems containing Cu, Fe, Zn, Mn, Ti as alloying elements. The investigation involves thermodynamic calculations and thermal analysis modeling stability and interactions of the nano modifiers with aluminum melt and gas environment (air, argon).

Approach

For the thermodynamic assessment of the interphase interactions of the nanoscale particles, we used the CALPHAD method of thermodynamic calculations of heterogeneous systems based on thermodynamic data for binary and ternary system elements.

When calculating the initial equilibrium state in the system, the thermodynamic data for chemical elements (constituents of the aluminum alloy) and carbides (which are used as a modifying additive). Study of the multicomponent system "aluminum alloy-nanoscale modifier", performed under the following boundary conditions:

- a closed heterogeneous "particle-melt" system was considered;
- particles - was an independent component of the calculation, with the amount limit up to - 5 wt. %.

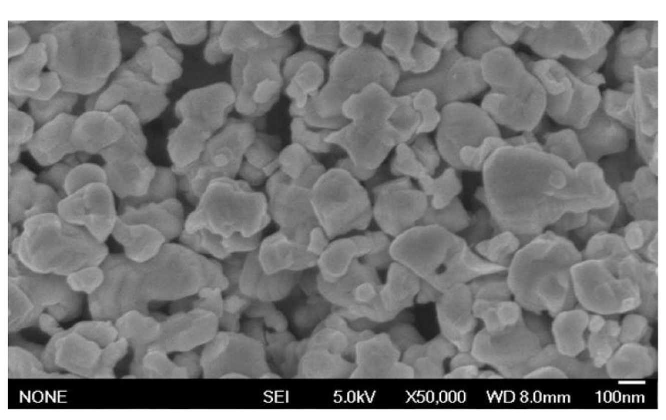
The thermal analysis was performed with synchronous thermal analyzer STA 449F1 Jupiter produced by NETZSCH STA in the sample with correction mode, in dynamic flow (20 ml / min) of argon and artificial air, for the studies aluminum oxide crucibles were used. The heating and cooling speed was 10 degree per minute.

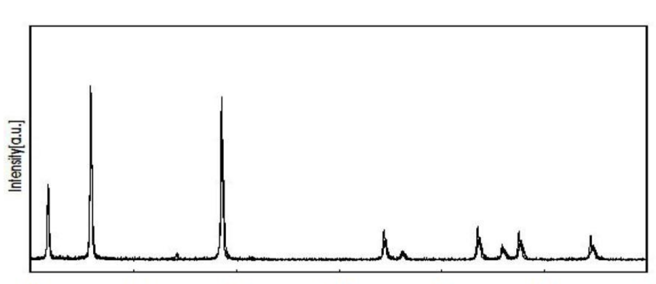
Nano-scale powders used in the work

Tungsten carbide

WC - 99,5 wt. %; APS - 200 nm; ρ - 15.6 g/cm^3

	wt. %
WC	99.0
T.C	0.28
F.C	0.1
Mg	0.001
Mn	0.001
Ti	0.001
Na	0.001
Al	0.001
Fe	0.002
Ca	0.001
Mo	0.001
Co	0.001
Cu	0.001
Cr_3C_2	0.1
VC	0.18
O	≦0.1

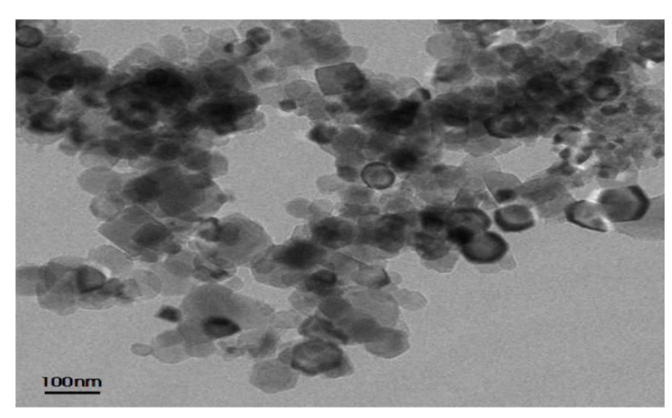


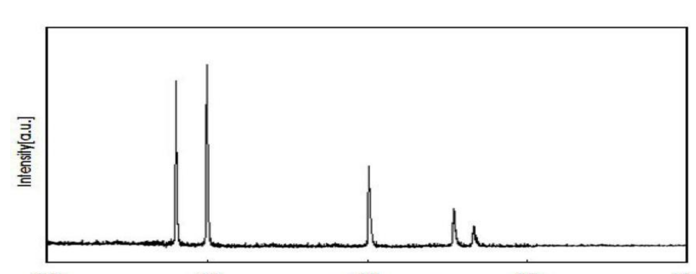


Titanium carbide

TiC - 99,9 wt. %; APS - 50 nm; ρ - 4,8 g/cm^3

	wt. %
TiC	99.9
Fe	0.002
Ca	0.001
Mg	0.001
Cu	0.001
Mn	0.002
Na	0.001
Zn	0.001
Al	0.001
Ni	0.001
Pb	0.001
K	0.001
N	0.01
F.C	0.2
S	0.001
O	0.1

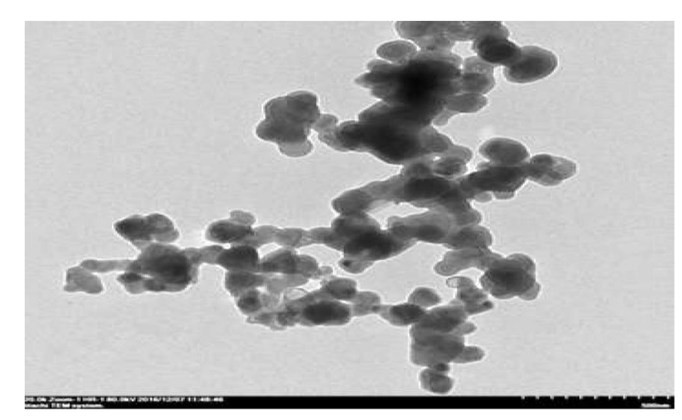


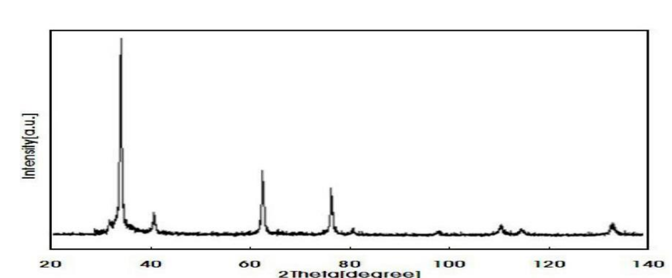


Silicon carbide

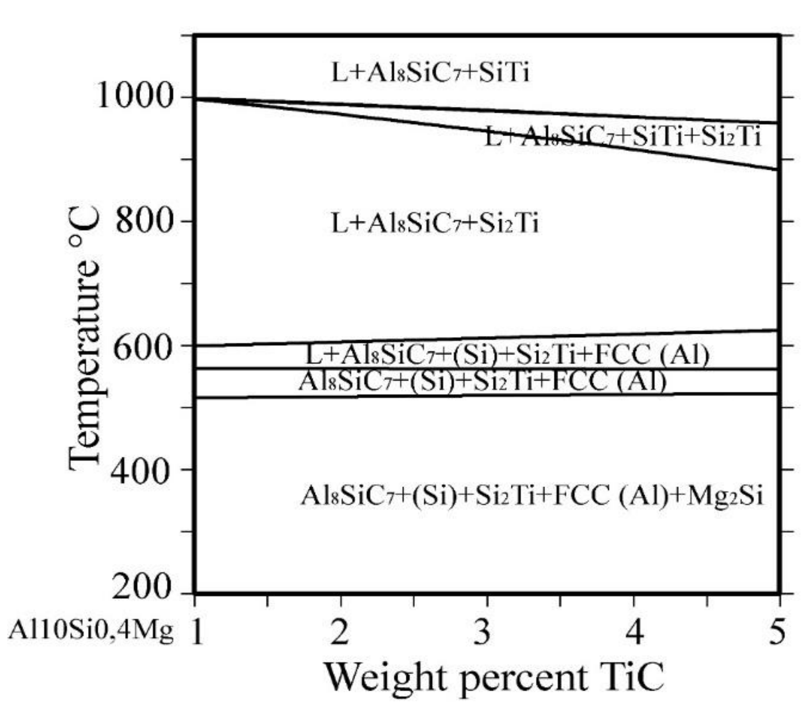
B SiC – 99,9 wt. %; APS - 50 nm; ρ - 3,2 g/cm^3

	wt. %
SiC	99.9
Fe	0.001
Ca	0.001
Mg	0.001
Cu	0.001
Mn	0.001
Na	0.001
Co	0.001
Al	0.001
Ni	0.001
Pb	0.001
K	0.001
N	0.001
F.C	0.02
S	0.001
O	0.1

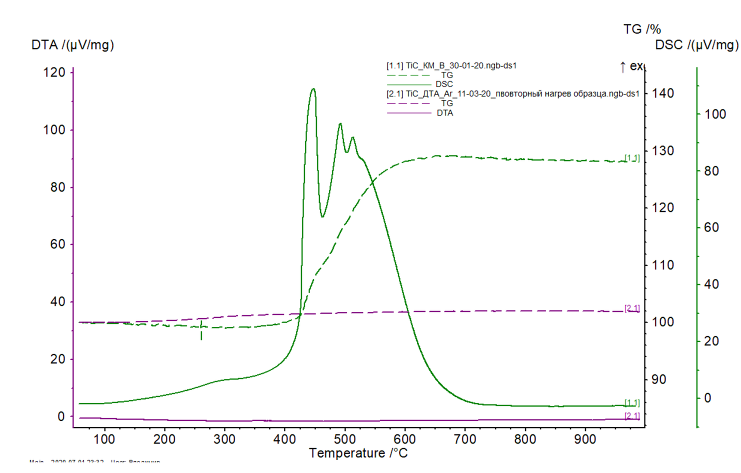




Results



Calculated phase diagram of Al10Si0.4Mg - TiC

a


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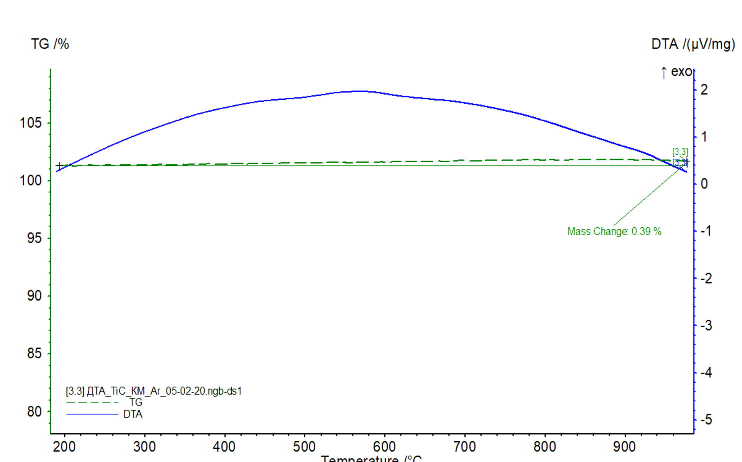
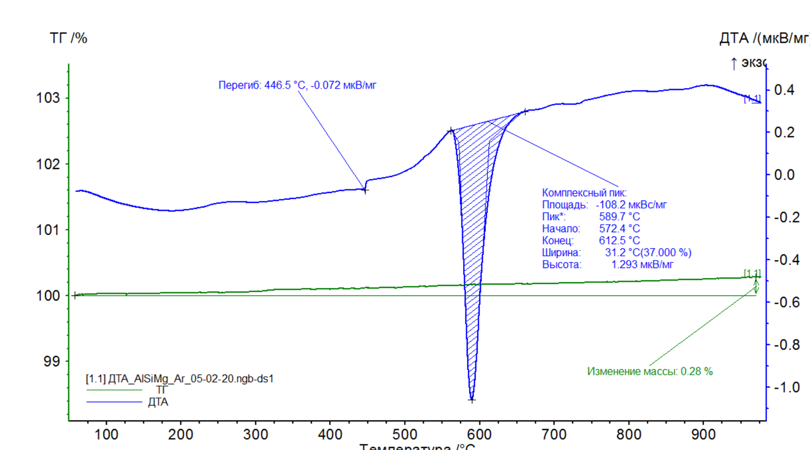


STA thermograms of titanium carbide nano-scale powder in air (a) and argon (b)

a


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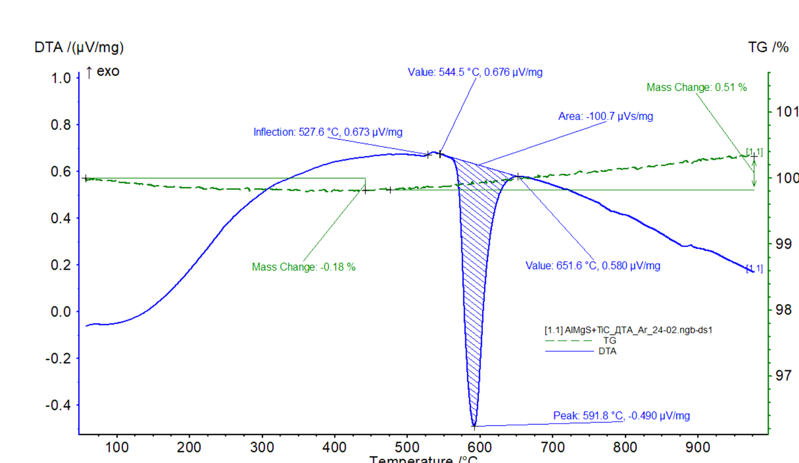

STA thermograms of Al10SiMg alloy(a) and titanium Al10SiMg modified with carbide nano-scale powder in argon (b)

Thermal analysis of nanoscale titanium, tungsten, silicon carbides under heating conditions in an atmosphere of artificial air and high purity argon was performed using a synchronous thermal analyzer. It was stated that all samples of carbides contain a sorbed moisture in the amount of up to 0.28 % by weight. Also, discovered that in the atmosphere of artificial air, powders of nanoscale titanium and tungsten carbides were actively oxidized at 425 °C and 476 °C, and completely turn into oxides at temperatures of 637 °C and 853 ° C, respectively. The active interaction of nanoscale silicon carbide particles was not stated up to 1000 °C, and has a slight weight loss at temperatures above 260 °C. For all investigated nanosized carbides up to a temperature of 1000 °C in the argon atmosphere thermal effects were not recorded.

Conclusion

It is shown that despite its relative instability, nanoscale TiC particles can be used as modifiers of aluminum alloys of the Al-Mg system, the presence of silicon reduces the stability of titanium carbide in the aluminum melts and therefore it`s presence is not desirable, the titanium, on the contrary, increases the TiC carbide stability. WC particles can be successfully used to modify the microstructure of the Al-Si alloy system, while the presence of silicon increases their stability in the melt. Particles of titanium diboride TiB_2 is the most stable compound of the studied particles, its insignificant modifying effect on aluminum alloys is compensated by its resistance to aluminum melts at significant overheating (above 1100 ° C).

It was discovered that welding aluminum alloys of the 4th series (Al-Si) containing 5 and more weight. % of silicon are promising materials for hardening with highly dispersed particles of tungsten carbide (WC), since they increase the stability of silicon-modifying particles. The presence of silicon up to 1 wt % in the Al-TiC system practically does not affect the interaction of titanium carbide particles with aluminum melts. An increase in silicon concentration leads to the formation of the titanium silicides (TiSi, $TiSi_2$) from the liquid phase, a further increase in the silicon content only enhances the interaction in this system.