Nano-scale non-metallic microstructure modifiers in materials for aluminum welding and 3D printing

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Objectives

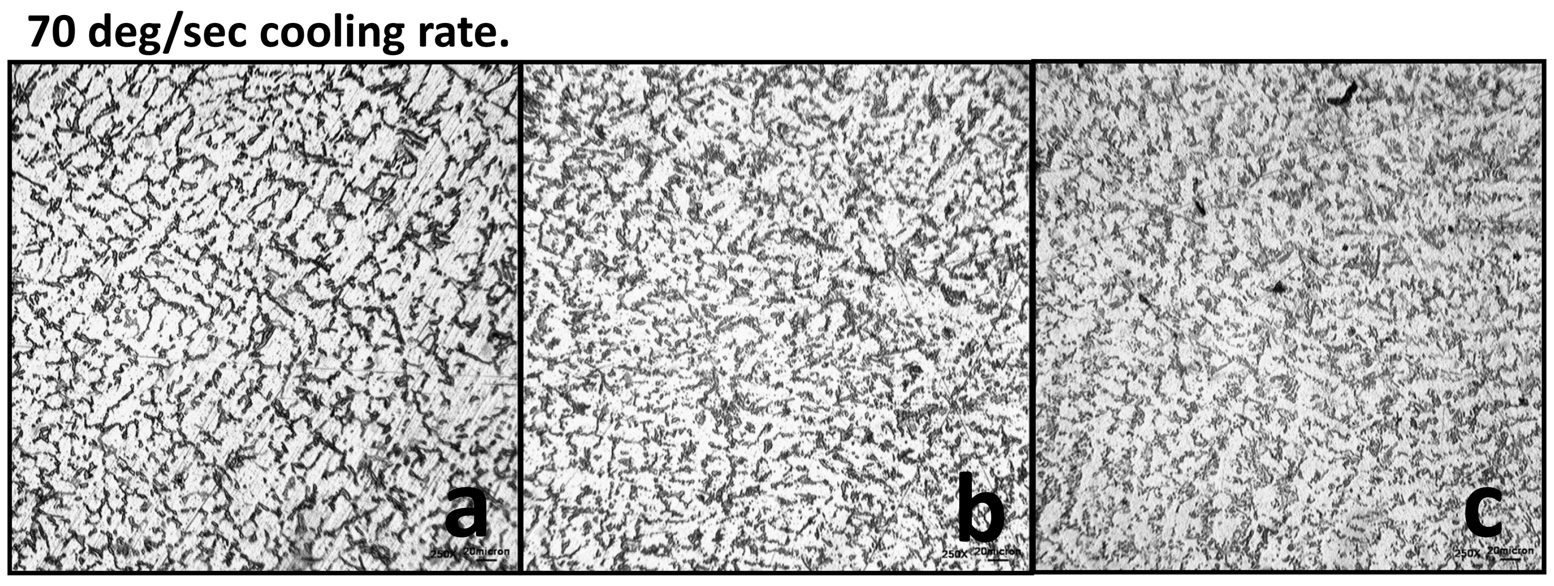
This study is discovering the affect of nano-scale nonmetallic modifiers on the formation of the structure of aluminum alloys in conditions simulates the formation of welds in fusion welding methods, primarily in arc welding methods. Discovering of such data allows to determine the ways for improvements in quality and strength of welded joints of aluminum alloys by strengthening them with addition of nanoscale modifiers as constituent of welding wires or fluxes and forming by that way composite structures. The important thing is discovering the conditions of chemical compatibility of the components of such composite structure, including thermodynamic and kinetic compatibility because of heterogeneity of such material. The study provides opportunities to formulate estimation of impact and stability of such nano-scale additions either in welding process and farther life of the weld.

Methods

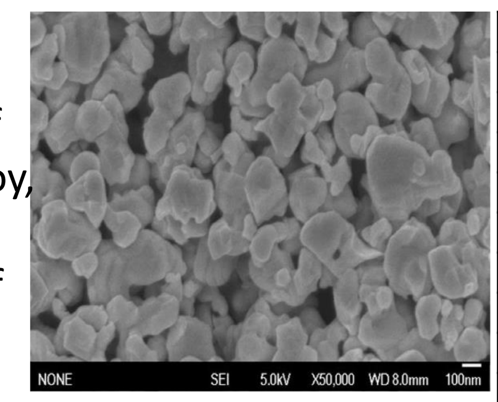
The approach is usage of theoretical thermodynamic CALPHAD calculations with experimental studies (microstructure and thermal analyzes) to discover features (atmosphere, time-temperature range, etc) within consolidation of nano-scale particles with aluminum alloys during welding process, to study the modifiers effect at microstructure of the crystallized melts at regimes modeling welding process and to evaluate their possible impact at welds characteristics.

Results

The result of Al10SiMg alloy melt modification by nano-cale 1 wt. % of tungsten and titanium carbide modifiers. Solidification accrued at 70 deg/sec cooling rate.

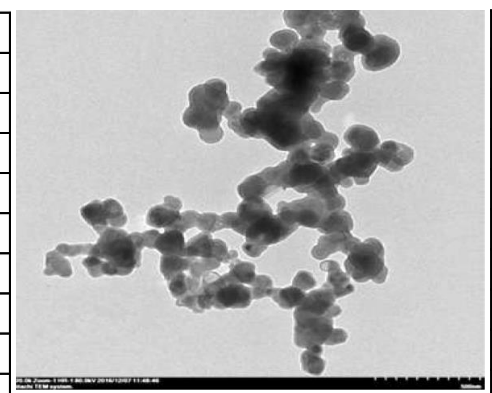


a - microstructure of as cast Al10SiMg alloy, x250;
b - microstructure of modified Al10SiMg alloy with titanium carbide, x250;
c - microstructure of modified Al10SiMg alloy with tungsten carbide, x250.



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

Conclusion

There were discovered number of the aluminum alloys systems: 5183, 4047, 4043, 1100, 5356 and 7075 to be modified by non-metallic microstructure modifiers to improve characteristics of its welding joints. Particularly for 4th series (Al-Si) aluminum alloys with Si content more than 5 wt. % and Al10SiMg alloy, currently actively used for 3D printing, is promising to improve its welding joints by highly dispersed nano-scale tungsten carbide introduced into melt at conditions of inert gas (argon) or covering flux. Correspondent to thermodynamic calculations, DSC and microstructure analysis 5 wt. % and higher silicon in aluminum alloy completely blocks formation of the aluminum carbide, phase equilibrium shifts towards formation of the tungsten silicide and silicon carbide, both of these compounds are highly stable in aluminum melts and form fine grain type microstructure for cooling rates from 8-10 deg/sec up to 70 deg/sec, these rates are correspond to melt crystallization conditions during arc and electron beam welding processes.