Formation of nanoscaled $Zr_{1-X}Ti_XC$ solid solution at mechanical alloying of 80ZrC-20TiC blend

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Introduction

Refractory TiC and ZrC monocarbides with the NaCl-type structures, as is known, have extremely high melting temperatures (3140 and 3532 ^{0}C, respectively), high hardness (31.4 and 26.2 GPa), high ductility with an elastic modulus of 400 and 460 GPa and with a shear modulus of 188 and 140 GPa, as well as high electrical conductivity, thermal conductivity and chemical resistance. The unique complex of such available physical properties ensures the use of bulk and thin-film materials with TiC and/or ZrC carbides as hardening additives for ceramic materials and protective coatings used for cutting tools.

Research metodology

In addition to pure ZrC and TiC carbides, their $Zr_{1-x}Ti_xC$ solid solution has certain prospects for practical application, too. Since the *Ab initio* phase diagram of the ZrC-TiC system, calculated in Ref [1], is asymmetric with greater solubility on the ZrC side, mechanical alloying (MA) synthesis was carried out here by treatment in a high-energy planetary mill (HEPM) of ZrC rich blend (mol. %): 80ZrC–20TiC. The test MA treated samples were studied comprehensively using X-ray method [2].

Results

It`s shown that the crystal structures of ZrC and TiC carbides, existing in test samples, are described well within the framework of the NaCl-type but with some vacancies of metal atoms in 4*a* set. That is, the impact loading, applied on the blend during MA, causes metal atoms knocked out of carbides with their gradual accumulation in the reaction zone of the HEPM in a form of individual clusters. As result of this process, at the first stage of MA the lattice parameter of ZrC carbide decreases substantially, while the TiC carbide begins to collapse fully. The next stage of the MA process there is a diffusion penetration of smaller titanium atoms into the ZrC lattice, which leads to a stepwise increase in its lattice parameter. It`s shown that after 5 hour of MA treatment in HEPM, the ZrC carbide dissolves about 12 at. % Ti, saving some amount of vacancies. Due to this fact, the value of the lattice parameter of ZrC carbide lies higher than Vegard's line (Fig.). The MA treated powder was HPHT sintered at 7.7 GPa, After HPHT sintering at 1500 ^{0}C the solubility of titanium atoms in the ZrC carbide save, while the increase in HPHT sintering temperature up to 2000 ^{o}C leads to increasing solubility up to 19 at. % Ti, that fully corresponds to the blend composition (Fig.).

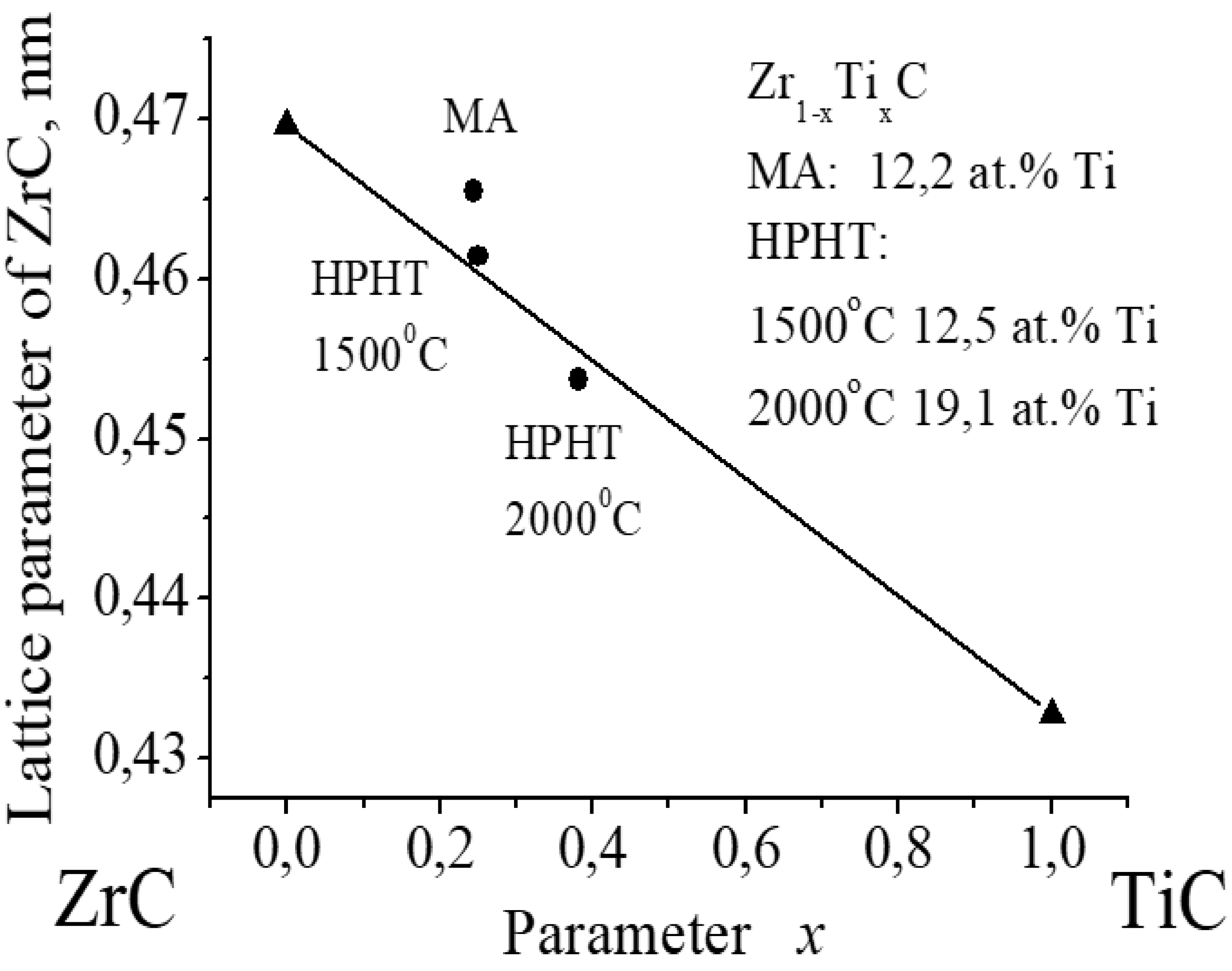

Fig. Vegard dependence for ZrC-TiC mixture (line) and experimental data obtained for $Zr_{1-x}Ti_xC$ solid solution formed in 80ZrC-20TiC mixture under MA and HPHT treatment (circles).

Conclusions

It`s first shown that sequential MA and HPHT treatments of the 80ZrC–20TiC blend lead to the formation of the nanoscaled (up to 30 nm) $Zr_{1-x}Ti_xC$ solid solution, containing up to 20 at. %Ti. The compact material obtained here will be tested for its further application.

References:

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