IRIDIUM – SILICON CARBIDE SYSTEM: INTERACTION PROCESSES, PRODUCT PROPERTIES, APPLICATION

M.A. GOLOSOV, A.V. UTKIN, V.V. LOZANOV, N.I. BAKLANOVA

Institute of Solid State Chemistry and Mechanochemistry SB RAS, Novosibirsk, Russia

Silicon carbide (SiC) is an essential component of high-temperature materials due to the combination of a number of useful properties. It has a high melting point (2730°C), high specific strength characteristics (compressive strength 2.8 Gpa, 600 MPa in bending), low density (3.21 g/cm^3), high thermal conductivity (120 W/m•K) and hardness (9 Mohs). Most of these useful characteristics are related to the strong covalent bonds with a dissociation energy of 4.6 eV. However, the high degree of covalent bonds (88%) and low self-diffusion coefficients result in a difficulty to sinter silicon carbide. Therefore, the joining of silicon carbide ceramics is a major challenge [1].

Recently, the joining of the SiC ceramics using a reaction/diffusion layer has gained wide interest [2]. As components of this layer, various substances can be served. The most promising approach is the use of refractory metals including Zr, Mo, W, Nb, and Ti or/and their alloys as components of the joining layer. One can note that these metals have a relatively low stability in oxidative environments [2]. The products of interaction these metals with silicon carbide are often incompatible with SiC due to the significant difference in molar volumes and coefficients of thermal expansion (CTE) [2].

Iridium is a promising component of the joining layer for SiC ceramics because it has a high melting point (2446°C). It is the most oxidation-resistant metal even at ultrahigh-temperatures (~2000°C) [3]. Further, the products of the interaction of iridium with silicon carbide are iridium silicide, IrSi, with a melting point of 1707°C, and carbon. The molar volume of the products differs from the molar volume of the reagents by less than 6%, and the volume CTE of IrSi is close to the volume CTE of SiC. Therefore, there is strong interest in the application of iridium as a bonding layer for SiC ceramics. However, the data on the mechanism of the reaction of iridium with SiC are limited and contradictory [4,5].

To investigate the features of the mechanism of iridium joining layer formation for SiC ceramics, phase formation, diffusion, and kinetics processes in Ir/SiC diffusion couples were studied in this work. In addition, CTE and Vickers microhardness values for some iridium silicides and thermal conductivity values for IrSi were obtained. SiC ceramic samples were also obtained SiC ceramics bonded using iridium under different conditions. It was obtained that the interaction products of iridium with silicon carbide are Ir_3Si, Ir_2Si, Ir_3Si_2, Ir_3Si_2, IrSi silicides and carbon. The final products under iridium-deficient conditions are IrSi and C. Iridium is the dominant diffusion atom. It was stated that the solid-state reaction occurring at the temperature lower than 1350°C is controlled by reaction, i.e., the reaction rate is lower than the diffusion rate. The lattice parameter changes of iridium silicides with temperature were determined from the full profile analysis of X-ray diffraction patterns and the CTE values of iridium silicides (Ir_3Si, Ir_2Si, Ir_3Si_2, IrSi) were calculated. The thermophysical characteristics of IrSi, namely heat capacity (C_p (IrSi) ~ 0.24 J/g•K) and thermal conductivity (~9 - 15 W/m•K) were also obtained. The thermal conductivity of IrSi is comparable to that of pure Ti (16 - 13 W/m•K) [6]. The bending strength for "SiC/Ir/SiC" parts obtained under conditions of solid-phase interaction was ~110 MPa.

REFERENCES

[1] Kim Y.-W., Malik R. SiC Ceramics, Structure, Processing and Properties // Encyclopedia of Materials: Technical Ceramics and Glasses / ed. Pomeroy M. Oxford: Elsevier, 2021. P. 150–164. doi: 10.1016/B978-0-12-818542-1.00022-9

[2] Liu G. Zhang, X., Yang, J. & Qiao, G. Recent advances in joining of SiC-based materials (monolithic SiC and SiCf/SiC composites): Joining processes, joint strength, and interfacial behavior // J Adv Ceram. 2019. Vol. 8, № 1. P. 19–38. doi: 10.1007/s40145-018-0297-x

[3] Jehn H., Volker R., Ismail M.I. Iridium Losses During Oxidation // Platinum Metals Rev., 1978, Vol. 22, № 3. P. 92-97. doi: 10.1595/003214078X2239297

[4] Yunfeng H. Zhengxian, L., Jihong, D. & Chunliang, H. Solid State Reaction of Ir with SiC and Ir with Y2O3 // Rare Metal Materials and Engineering. 2012. Vol. 41, № 7. P. 1149–1152. doi: 10.1016/S1875-5372(12)60059-9

[5] Camarano A., Narciso J., Giuranno D. Solid state reactions between SiC and Ir // Journal of the European Ceramic Society. 2019. Vol. 39, № 14. P. 3959–3970. doi: 10.1016/j.jeurceramsoc.2019.06.009

[6] Ślęzak T., Zmywaczyk J., Koniorczyk P. Thermal diffusivity investigations of the Titanium Grade 1 in wide temperature range. Smolenice, Slovakia, 2019. P. 020019. doi: 10.1063/1.5132738

* The work was supported by the Russian Science Foundation (Project No. 23-19-00212).