Effect of gold sputtered ceramic nanoparticles on the microstructure and shear strength of lead-free solder joints

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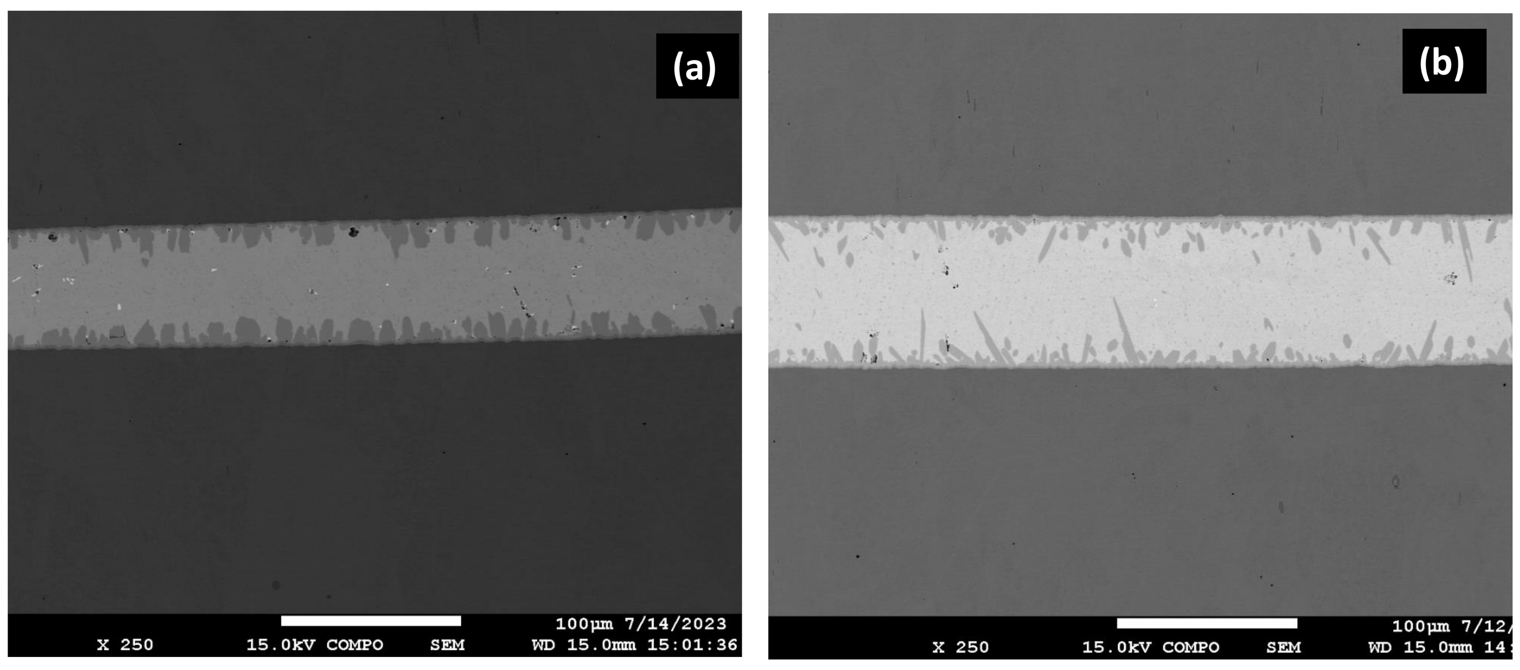
Introduction

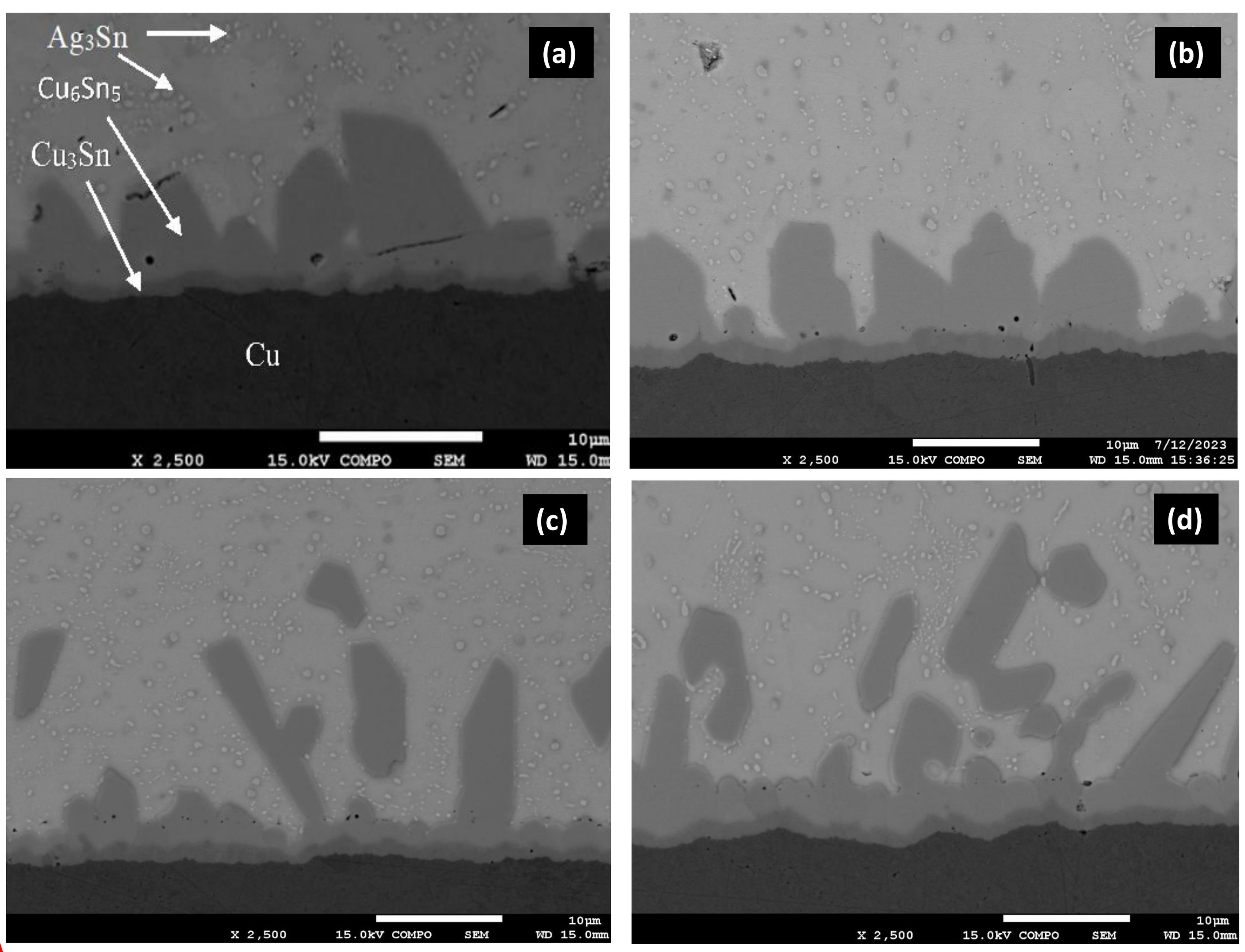
- To improve the properties and strengthen the base lead-free solder (LFS) matrix, various nano-sized ceramic admixtures are added.
- Ceramic admixtures are non-wettable by metal melts, therefore, metallic coatings are applied to their surface to form core-shell structures and to improve adaptation to the solder matrices. The metal-coated layer forms a strong "bridge" that reacted with the LFS matrix to form an intermetallic layer during soldering.
- The effect of ceramic Al_2O_3, TiO_2, SiO_2 and ZrO_2 admixtures coated with Au on the properties and microstructure of the solder joints based on Sn-Ag-Cu was studied at elevated and sub-zero temperatures.

Methods

- Ternary Sn96.5Ag3Cu0.5 (wt.%) (SAC305) was taken as the basic alloy.
- Ceramic nanoadmixtures were coated by Au nanoparticles using Coater Bio-Rad E5100.
- Zwick/Roell Z 100 was used for push-off tests.
- The microstructure was investigated by SEM. JEOL JSM-7600F and JEOL JSM-6610 equipped with EDX analyzer.

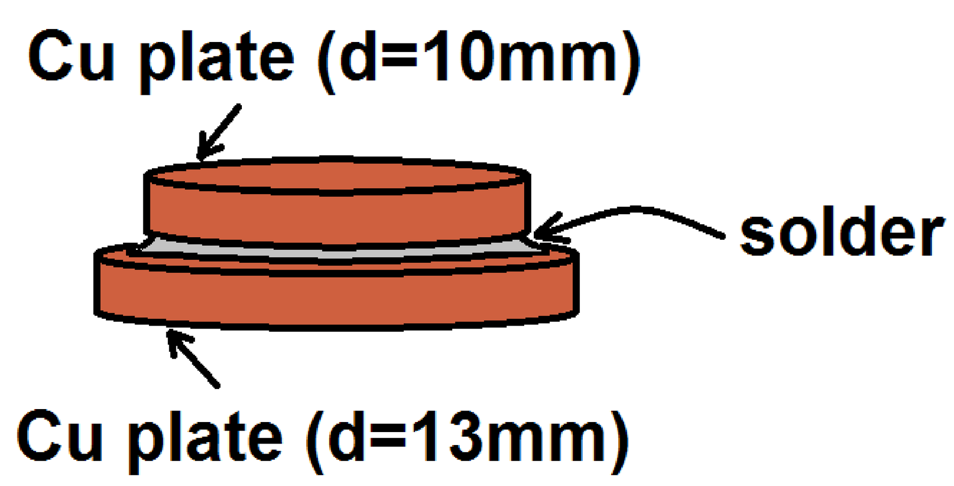


Microstrucuture of the Cu/SAC305/Cu soldered cross-section before (a) and after aging for 2 months at 253 K (b)

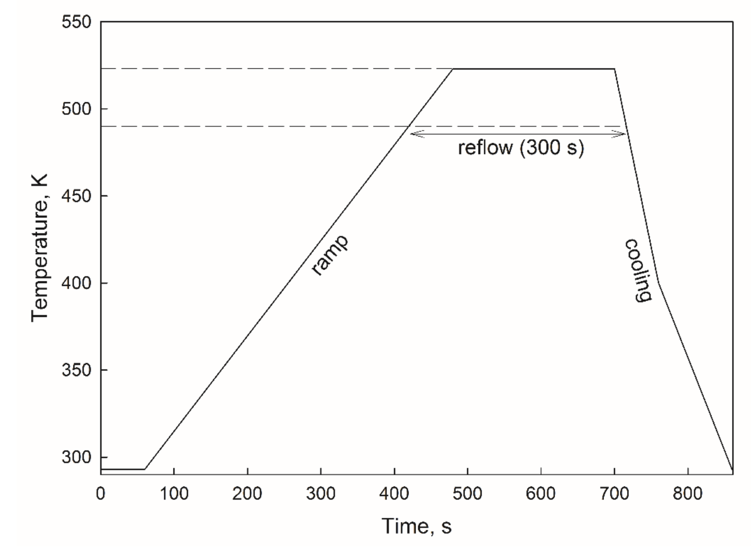


SEM micrographs of SAC305 (a) and SAC305+TiO2+Au (b) at RT; SAC305 (c) and SAC305+TiO2+Au (d) aged for 2 months at 253 K

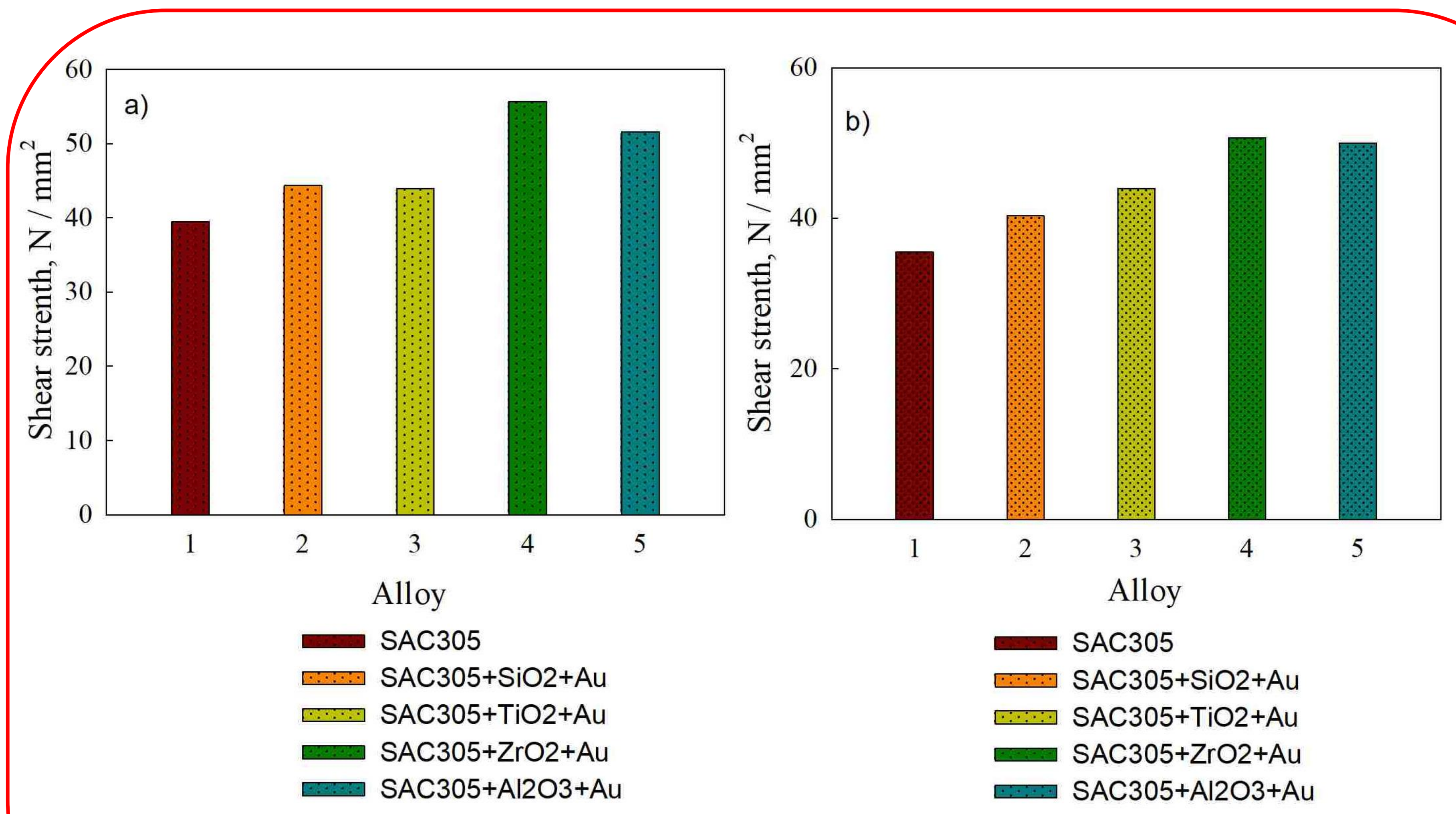
Results



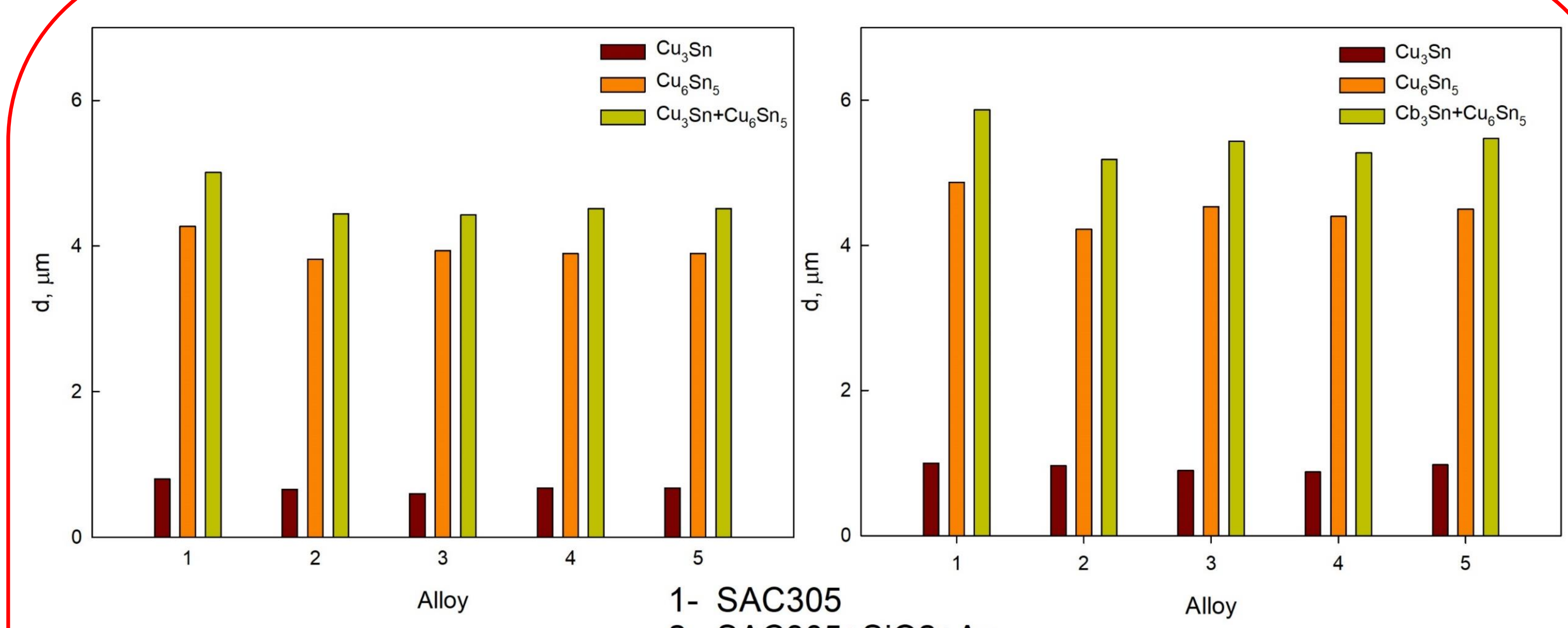
Scheme of the Cu/solder/Cu joint



Reflow temperature profile of solder-Cu joint



Shear strength of the nanocomposite SAC305 solder joints at 293 K (a) and after 2-month aging at 253 K (b)



1- SAC305
2 - SAC305+SiO2+Au
3 - SAC305+TiO2+Au
4 - SAC305+ZrO2+Au
5 - SAC305+Al2O3+Au

Average thickness of the interfacial Cu_3Sn and Cu_6Sn_5 IMCs layers formed at the as-reflow Cu/nanocomposite SAC305/Cu at 293 K (a) and after 2-month aging at 253 K (b): 1 – SAC305; 2–SAC305+SiO2+Au; 3–SAC305+TiO2+Au; 4–SAC305+ZrO2+Au; 5–SAC305+Al2O3+Au

Conclusion

As a result of prolonged exposure at a low temperature of 253 K, the thickness of the IMC layers formed in Cu pairs soldered with SAC305 nanocomposite solders containing Au-coated ceramic nanoparticles increases more slowly than in the case of solders without admixtures. The addition of coated ceramics increases the shear strength of the solder joints.

The use of the nanocomposite SAC305 solders in electronic devices operating at temperatures as low as –20 °C is possible at least up to 2 months, by remembering that further growth of IMC layers up to the dimensions of the joint width between the soldered parts can cause the change of solder structure from ductile to quasi-ductile and later to quasi-brittle one, until the brittle fracture mode is attained.

Acknowledgements

The work was supported by the Office of Government of Slovakia, project 09I03-03-V01-00047; by the SRDA, project APVV SK-UA-21-0076; by Ministry of Education and Science of Ukraine, projects 0122U002643, 0122U001521

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