

Technology News

Brazing for Facility Repair and Habitat Construction in Sustainable Space Exploration

Technological aspects of the exploration of nearby planets are increasingly being discussed by the engineering community. And the turn has come for brazing and soldering, which will be present in the lunar and Martian cities, along with welding.

Scientists at the Harbin Institute of Technology, Harbin, China, have considered the possibility of brazing using glass solder based on regolith, which is a common raw material on these planets (Ref. 1). Pressureless, sintered silicon carbide (SiC) ceramic was used as the base material, and brazing was carried out in an argon tube furnace at a temperature of 1400°C (2552°F). The resulting brazed joints were dense and almost homogeneous, the phase separation was local and insignificant, and the shear strength of the joints reached 27.3 MPa, which is low compared to the strength of SiC joints manufactured in terrestrial conditions. Because the gravitational forces on the Moon are only 1/6 and on Mars 1/3 than those on Earth, we can expect much less mechanical load acting on brazed or welded joints there. It should also be noted that the glass transition temperature of the regolith in the joint is ~657°C (~1214.6°F), which means the brazed joints are suitable for high-temperature applications.

Reliable Inspection of Ceramic-to-Metal Brazed Joints by 3D Computed Tomography

X-ray radiography of ceramic-to-metal brazed joints typically requires long tuning and confirmation of results by application of different inspection methods (e.g., helium-leak tests). The problems of interpreting x-ray images and the accuracy of measuring defects are caused by the different physical properties of the brazed structure components, especially at different

thicknesses of ceramics, the base metal, and the joint metal.

Ongun, E., and Genç, G., from Ankara, Turkey, presented a fast and reliable method of radiography of alumina-to-Kovar brazed structures by 3D computed tomography, which allows quick and accurate detection of defects in brazed joints, including defects in fillets. Resolution of this technique in an image was 15–20 microns, the number of projection was 2000, computed tomography scan time was 3–20 minutes, and total process time was 4–30 minutes (Ref. 2). The method provides the inspection of all the joints in the brazed structure at once, regardless of the size ratio of ceramic-to-metal parts.

Brazing and Interfacial Reaction between Active Ti and a Ceramic with Negative Thermal Expansion

Ceramics based on molybdenum or tungsten oxides exhibit a negative coefficient of thermal expansion (NTE). Therefore, they have recently been considered as filler materials capable of reducing residual thermal stresses in welded and brazed joints of thrust chambers and nozzles of spacecraft engines.

Wetting and interfacial reactions of a Ticusil®-type active brazing alloy with powder of one of such ceramics, $\text{Sc}_2\text{W}_3\text{O}_{12}$, was studied at the Harbin Institute of Technology, Harbin, China (Ref. 3). It was found that thanks to the strong interfacial reaction between the active Ti and $\text{Sc}_2\text{W}_3\text{O}_{12}$ filler, mismatch of thermal expansion between AgCuTi joint metal and base materials was significantly decreased. As a result, residual stresses in the SiC-GH3536 superalloy joints decreased from 445 to 374 MPa. Due to lower residual stress, the shear strength of 77 MPa was realized by the composite filler metal at 860°C (1580°F), which was 3.2 times higher than that of brazed joints made with AgCuTi braze alloy without an NTE ceramic filler.

Laser-Based Metallization of Materials with Low Wettability

Metallization of the ceramic surfaces or other poorly wetted materials is one of the successful methods for improving the wettability and quality of brazing. However, metallization is a rather complex multistage process that also requires additional inspection and quality control.

Scientists from the Fraunhofer Institute for Laser Technik, Aachen, Germany, found a technologically simple and reliable method of local laser metallization of materials having low wettability (Ref. 4). We are talking about poorly wetted ceramics, such as SiC, SiSiC, Si_3N_4 , Al_2O_3 , BN, WC, and ZrO_2 , on the surface of which a layer of 20–60 microns silver was applied. This thickness is preferable for subsequent soldering with active solders. It should be noted that the thickness of metallization applied by the methods used now in the industry is either significantly less (2–6 microns for physical vapor deposition coating) or significantly thicker (200–500 microns for plasma spraying). The source of silver was a slurry containing Ag nanoparticles. The slurry was deposited onto a ceramic surface that was treated by a laser beam of 5–25 W of power. The scanning speed was ~50 mm/s. The deviation in layer thickness from sample to sample was up to 40%. At the same time, the temperature of the process was halved compared to known metallization methods. Batteries, fuel cells, and heat exchangers are among the promising applications.

Simple Method of Metallization with Ceramic by Overheating a Tin Solder in Vacuum

A simple and reliable method of metallization of ZrO_2 ceramic has been proposed by the Harbin Institute of Technology, Harbin, China. It consists of surfacing low-melting solder Sn-3Ti on

the ceramic surface in vacuum with significant overheating above the melting point of the solder, namely at 1000°C (1832°F) for 30 minutes (Ref. 5). Then soldering zirconia ceramic to titanium is easily performed with standard inactive solder Au-20Sn by heating in vacuum to 450°–650°C (842°–1202°F) for 30

minutes. At the same time, a layer of triple Au-Sn-Ti alloy is formed on the surface of the titanium, the thickness of which strongly depends on the soldering temperature: 5–10 microns at 450°–600°C (842°–1112°F) and 30 microns at 650°C. The maximum strength (48 MPa) of the soldered joint

of metallized ceramics to titanium was obtained at 550°C (1022°F), while it was only 20–25 MPa at soldering temperatures of 450° or 650°C.

Mechanical Properties of High-Entropy Ceramic Joints

Over the past ten years, we have become accustomed to the term high-entropy brazing alloys. Many studies and publications have confirmed that these new alloys can increase the strength of brazed structures and are promising for various applications from electronics to spacecrafts. However, all the high-entropy alloys developed so far are related to brazing metals.

Scientists from Tianjin University, Tianjin, China, investigated the brazing process of high-entropy ceramic HfTaZrNbTiC_5 and tested mechanical properties of brazed joints of this carbide ceramic (Ref. 6). The ceramic was manufactured by hot pressed sintering of fine powders of simple carbides TiC, HfC, NbC, ZrC, and TaC. The eutectic Ti-40Ni-20Nb (at.-%) was used as a filler metal for vacuum brazing at 1220°C (2228°F) for ten minutes. The shear strength of brazed joints reached 167 MPa at room temperature but only 22 MPa at 800°C (1472°F) after oxidation for eight hours. It's important to note that the oxidation damaged the ceramic and almost did not affect the joint metal. It seems that the brazing method has been found, whereas high-entropy ceramic needs improvement.

Effect of the External Magnetic Field on the Spreading of Molten Metal

The positive effect of electric current on the wetting and spreading of solder or braze alloy has been studied extensively. When the solder melts, a short circuit occurs and is difficult to control, especially with high-temperature soldering. The use of a magnetic field does not require direct contact, but the magnetic properties of metals depend on temperature. Therefore, new data on the influence of the magnetic field are always of interest.

"WORLD LEADERS IN SUBMERGED ARC FLUX HANDLING EQUIPMENT"

Contact us for your Submerged Arc Flux Handling solutions.
Phone: (508) 842-2224
Fax: (508) 842-3893
Email: sales@weldengineering.com

WELD ENGINEERING CO., INC.

To View All Our Equipment Go To:
www.WeldEngineering.com

Flux Recovery
WELD ENGINEERING CO.
WORLD LEADERS IN SUBMERGED ARC FLUX HANDLING EQUIPMENT
Earth Resource Recovery

AS-4
ELECTRIC STANDARD DUTY FLUX RECOVERY EQUIPMENT

ALT-2
ELECTRIC AND AIR TRACTOR FLUX RECOVERY EQUIPMENT

AP-1
AIR POWERED STANDARD DUTY FLUX RECOVERY EQUIPMENT

XP-4T

PT-100
PRESSURE FEED FLUX TANK

MM-3000X

HPT-100
HEATED AND UNHEATED PRESSURE FEED SYSTEMS

HAMX-50
HEATED AUTO-MIXING SYSTEMS

HTB-700-550° OVEN

FFO-100-AS OVEN

FULL LINE OF FLUX REBAKE OVENS

MM-5000X

HPFR-3000-H100/H200

HEATED AND UNHEATED PRESSURE FEED AND RECOVERY SYSTEMS

COMPLETE PIPE MILL FLUX HANDLING SYSTEMS

EXTREME HEAVY DUTY VACUUMS

SAVE FLUX, SAVE MONEY, SAVE THE EARTH.

The effect of the external magnetic field (EMF) on spreading molten aluminum on steel during the gas metal arc braze welding process was studied at the China University of Mining and Technology, Xuzhou, China (Ref. 7). Different shapes of magnets at varied magnetic flux density were tested. With the increment of the applied EMF strength, the spreadability of the molten aluminum was enhanced and the width of the brazed joint increased. Optimal EMF parameters were found to decrease the wetting angle. The enhancement of molten metal spreading under the action of EMF resulted in higher tensile strength of the joints.

Ultrasonic-Assisted Soldering of Ceramic in Air without Active Filler Metals

The possibility of metallization and soldering of Al_2O_3 or silicon carbide (SiC) ceramics by flux-free, ultrasonic-assisted soldering in air using simple Zn-2Al solder was proved at the Fraunhofer IKTS, Hermsdorf, Germany, and Euromat GmbH, Baesweiler, Germany (Ref. 8). The solder was activated via an encapsulated ultrasonic transducer consisting of a piezoelectric system oscillating at 60 kHz and thin titanium sonotrode. The soldering temperature was $420^\circ\text{--}450^\circ\text{C}$ ($788^\circ\text{--}842^\circ\text{F}$). Shear strength of alumina-to-alumina joints was up to 25 MPa, SiC to SiC was up to 20 MPa, and SiC ceramic to aluminum metal was up to 30 MPa. Metallization can be performed by operation under argon. The solder layer on the ceramic was dense and uniform. The solder demonstrated good adhesion to ceramics, which can be attributed to the additional energy input by ultrasound in the special acoustic cavitation and streaming effects. Then the metallized ceramics can be soldered in air to any metals by the traditional soldering process with any standard fluxes. [WJ](#)

References

1. Zheng, W., and Qiao, G. 2022. Brazing of SiC ceramic with extraterrestrial regolith simulant in ISRU and ISRF applications. *Advances in Space Research* 70: 752–761.
2. Ongun, E., and Genç, G. 2022. Non-destructive evaluation of ceramic-to-metal

brazed joints by means of x-ray inspection and helium leak detection techniques. *Proceedings of the 13th International Brazing and Diffusion Bonding Conference LÖT-2022*, 254–268. Aachen, Germany: DVS.

3. Wang, P., Xu, Z., Liu, X., et al. 2022. Regulating the interfacial reaction of composite filler $\text{Sc}_2\text{W}_3\text{O}_{12}/\text{AgCuTi}$ by introducing a carbon barrier layer. *Carbon* 191: 290–300.

4. Maischner, D., Weisheit, A., Rass, I., et al. 2022. Laser based metallization of materials with low wettability for joining of hybrid material combinations. *Proceedings of the 13th International Brazing and Diffusion Bonding Conference LÖT-2022*, 221–225. Aachen, Germany: DVS.

5. Lei, Y. Z., Bian, H., Jang, N., et al. 2022. Low temperature brazing of biomedical titanium and zirconia metallized with Sn-Ti metal foil. *Materials Characterization* 193: 1–11.

6. Sun, K., Yang, Z., Mu, R., et al. 2022. High-temperature stability of microstructure and mechanical properties of

eutectic-reinforced high-entropy ceramic joint. *Journal of the European Ceramic Society* 42: 4436–4445.

7. Wang, L., Ma, Y., Xu, J., et al. 2022. Improving spreadability of molten metal in MIG welding-brazing of aluminum to steel by external magnetic field. *Journal of Manufacturing Processes* 81: 35–47.

8. Steinborn, C., Rass, I., Kolberg, J., and Martin, H.-P. 2022. Joining of ceramics: Solders, surface activation, stress reduction and achieved properties. *Proceedings of the 13th International Brazing and Diffusion Bonding Conference LÖT-2022*, 203–210. Aachen, Germany: DVS.

Information provided by **ALEXANDER E. SHAPIRO** (ashapiro@titanium-brazing.com) and **LEO SHAPIRO**, Titanium Brazing Inc., Columbus, Ohio.

TEST YOUR OWN WELDS



• Bend Testers

BTIC



• PerfPods™
Performance Positions On Demand



• Coupons

Visit our website for all available sizes and models



• Bend Specimen Cutters



• Tensile Testers

Fischer ENGINEERING Company

FECo

www.fischerengr.com (937)754-1750

welding ENGINEERING SERVICES

Helping industry meet welding codes and standards since 1976!