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ELECTROCHEMICAL CORROSION AND LONG-TERM OXIDATION RESISTANCE OF Ti-Al-C, (Ti,Mo)-Al-C AND (Ti,Cr)-Al-C COATINGS DEPOSITED BY HYBRID MAGNETRON SPUTTERING AND CATHODIC ARC EVAPORATION METHOD

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sips24_43_409

Molten Carbonate Fuel Cells (MCFCs) are a relatively recent development in fuel cell technology, with applications ranging from small to large scale power generation systems. The interconnect is the part of the MCFC to which the anode and cathode are attached and through which the electrical current generated by the cell is conducted. Therefore, the interconnect must not only be mechanically strong and resistant to oxygen and hydrogen, but also maintain high electrical conductivity and corrosion resistance (including on the surface of the interconnect) at high temperatures (550...650°C) for long periods.

Interconnections (0.3-0.5 mm thick) made of stainless steel (which contains 16-18% Cr and has a high density γ ~ 8 g/cm3) lose surface electrical conductivity due to oxidation. MAX phases Ti_2AlC_3 and Ti_2AlC have two times lower density (γ ~ 4.1 - 4.3 g/cm^3) than stainless steel, are stable in oxygen and hydrogen atmosphere at high temperature, and have high electrical conductivity. Therefore, the MAX phase based coatings are potentially promising for this application. OT4-1 titanium alloy substrates with protective coatings are being developed for use as interconnects for MCFCs to replace 316L stainless steel.

Ti-Al-C, (Ti,Mo)-Al-C and (Ti,Cr)-Al-C coatings were deposited on OT4-1 alloy substrates by hybrid magnetron sputtering and cathodic arc evaporation. For magnetron sputtering, a MAX phase (Ti_2AlC - 63 wt.% and Ti_3AlC_2 - 37 wt.%) target prepared by hot pressing of TiC, Al and TiH_2 under 20 MPa, at 1350 °C for 10 min was used. Simultaneously with magnetron sputtering of the MAX phase target, chromium or molybdenum was deposited using a cathodic arc plasma source. Three types of coatings were deposited: Ti-Al-C magnetron-only and hybrid (Ti,Mo)-Al-C and (Ti,Cr)-Al-C. The thickness of the deposited coatings was 5-11 µm.

X-ray diffraction analysis showed that all deposited coatings are close to amorphous state. The SEM-EDX study indicated that the average composition of the coatings obtained from the MAX phase based target was $Ti_2Al_{1.0-1.1}C_{1.1-1.3}$ (close to 211), for the coating with additions of Mo: $Ti_2 Mo_{2.1}Al_{0.9}C_{2.8}$ (close to 413) and Cr: $Ti_2Cr_{2.6}Al_{0.8}C_{1.5}$. The nanohardness of the coatings varied from 11 to 15 GPa and the Young's modulus from 188 to 240 GPa.

The (Ti,Cr)-Al-C coating showed the highest stability against electrochemical corrosion in 3.5 wt.% NaCl aqueous solution at 20 °C: corrosion potential E_{corr} = 0.044 V, corrosion current density $i_{corr} = 2.48\times10^{-9}$ A/cm^2, anodic current density i_{anodic} (at 0.25 V vs. SCE) = 5.18×10^{-9} A/cm^2. This coating also showed the highest long-term oxidation resistance and after heating in air at 600 °C, 1000 h its electrical conductivity $\sigma = 9.84\times10^6$ S/m was slightly higher than before heating $\sigma = 4.35\times10^5$ S/m, the nanohardness and Young's modulus are in the range of 15 GPa and 240 GPa, respectively. The increase in electrical conductivity after long-term heating at 600 °C can be explained by the observed crystallization of the amorphous phase in the structure of the coating.

Thus, the hybrid deposited (Ti,Cr)-Al-C coatings exhibit high corrosion and oxidation resistance while maintaining electrical conductivity and can be used to protect titanium alloy interconnects in lightweight MCF cells.

Acknowledgments *The work was supported by the III-7-22 (0785) Project of the National Academy of Sciences of Ukraine "Development of wear-resistant electrically conductive composite materials and coatings based on MAX phases for the needs of electrical engineering, aviation, and hydrogen energy"; by the NATO project SPS G6292 "Direct liquid fuelled molten carbonate fuel cell for energy security (DIFFERENT)", and by the MES Ukraine project №0122U001258 "Development of nanotechnological methods to prevent corrosion of structural materials in thermal and nuclear power plants".*

Keywords:
Interconnects of Molten Carbonate Fuel Cells (MCFCs); Electrochemical corrosion; Long-term oxidation resistance; Ti-Al-C, (Ti,Mo)-Al-C, (Ti,Cr)-Al-C coatings; Hybrid magnetron sputtering and cathodic arc evaporation