Protective coatings based on CrN for current collector materials of molten carbonate fuel cells

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Bipolar plates and current collectors are critical metallic components for commercial MCFC stacks. In fact for commercial MCFC systems, up to 55 % of the material content could be the metallic hardware (for the complete system) which includes cell, stack, and balance-of-plant materials. The stability in a corrosive carbonate atmosphere at high temperature, good electrical conductivity and low contact resistance with the electrodes are desired characteristics of bipolar plates and current collectors. The bipolar plates are exposed to different atmospheres on the anodic side, cathodic side, and wet seal area of MCFC, and hence the ideal material for bipolar plate current collectors should have acceptable corrosion resistance for all of these atmospheres. Stainless steels like 310 S (24–26 wt. % Cr) and 304 L (16–18 wt. % Cr) have emerged as materials of choice for MCFC hardware [1]. However, the hot corrosion in the presence of the carbonate melt is a critical issue with these materials for long-term operation. During the period of initial operation, the mechanism of corrosion in these steels is normal corrosion involving scaling via the formation of a layer of iron oxides on the chromium-rich oxide layer. One of the methods of protecting and improving the corrosion properties of steels is the application of coatings based on nitrides. The corrosion resistance of Cr-N coatings is better than that of the stainless steel and other nitride coatings in the high temperature pressurized water and the oxidation rate in air at 600/800°C is low [2].

304L stainless steel specimens of sizes 0.4 × 25 × 25 mm^3 were used as substrates. The coatings were deposited on polished stainless steel samples using a Cr cathode and the vacuum arc method. The chamber was evacuated to a pressure of 1×10^{-3} Pa. Argon gas was introduced into the vacuum chamber up to pressure 5×10^{-2} Pa for stable burning of the arc discharge. During the deposition of the chromium nitride layer, the nitrogen filling pressure was 2 Pa (variant #1 and #3) and 0.2 Pa (variant #2 and #4 Table 1). To avoid diffusion of chromium from the substrate during long-term oxidation, it was suggested to apply a protective copper sublayer (variant #3 and #4 Table 1).

Table 1. PVD modes and thickness of the obtained coatings

	Pressure of N_2, Pa	Bias voltage, V	Thickness Cu, μm	Thickness CrN, μm
#1	2	150	-	16.6
#2	0.2	120	-	6.9
#3	2	150	0.3	4.1
#4	0.2	120	0.3	2.2

The X-ray diffraction study was performed in monochromatic Cu Kα radiation using STOE powder diffraction system in a focusing Bragg-Brentano geometry (Fig. 1). Oxidation resistance and electrical conductivity of coatings after long-term (1000 h) holding at 600°C in air were studied. Electrical conductivity of obtained coating was $3.5\cdot10^5$ S/m.

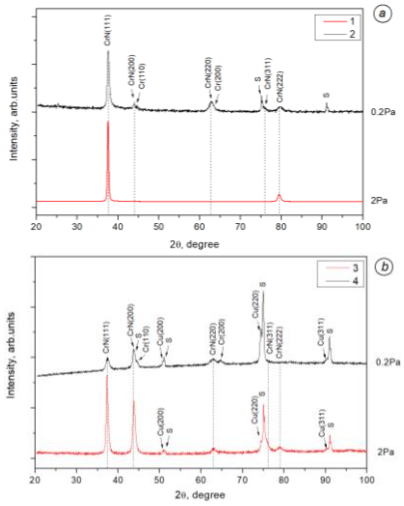

Figure 1. X-ray of samples with coatings of the Cr-N system deposited on a steel substrate without Cu sublayer (*a*) and with Cu sublayer (*b*).

It was established that coating variant #1 has the highest oxidation resistance, but coating variant #4 has greater electrical conductivity after long-term exposure at 600C in air.

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References

[1] Frangini, S. et al. Front. Energy Res. 9:653531. doi: 10.3389/fenrg.2021.653531 (2021).

[2] Kuprin, A. et al. Journal of Nuclear Materials, 465, 400-406. (2015).

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