Advanced TEM Investigation of Interfaces in As-Prepared and Corroded Al-Al_2O_3 Cold Sprayed Coatings on Steel

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Nowadays, cold spray coating is recognized as a leading thermal spray process with a high potential to meet industrial demands [1]. Most popular materials used in cold spray are aluminum (Al) and its alloys due to their low density, deformation rate and ductility. Aluminum coating properties can be improved by mixing ceramic particles such as B_4C, TiN, SiC or Al_2O_3, with aluminum powder [2]. These improvements result from the well-known hammering effect of ceramic particles during spraying. Hence, alumina (Al_2O_3) addition is known to reduce coating porosity and increase deposition efficiency and hardness [3]. However, this is not really understood today and requires observation of Al/Al_2O_3 interfaces down to a very fine scale.

In this work, both spherical aluminum (Al) and 15% wt. alumina (Al_2O_3) powders were mixed to achieve high-performance cold-sprayed coating onto steel. Using Transmission Electron Microscopy (TEM) and associated techniques (HRTEM, EDX, STEM-HAADF, electron tomography), Al/Al and Al/Al_2O_3 interfaces were investigated at a nanoscale to understand the strengthening effects caused by embedded hard particles within a composite coating. Interface improvement was shown to result from alumina addition. Al/Al_2O_3 interfaces showed a clean aspect with no porosity even at nanoscale, unlike Al/Al interfaces were nanoporous (Fig. 1). Electron tomography revealed that nanopores are interconnected forming a network.

These results explained why the addition of Al_2O_3 improves significantly the coating resistance to corrosion in the marine environment. Nanopores network in Al/Al interfaces facilitates corrosive agent penetration. Indeed, TEM investigations carried out on corroded Al-Al_2O_3 coating highlighted that no corrosion products are present at Al/Al_2O_3 interfaces in contrast to Al/Al interfaces. Using electron diffraction, EDX and EELS experiments corrosion products have been identified as being probably a mixture of Al_2O_3 and $Al(OH)_3$ (Fig. 2).

References:

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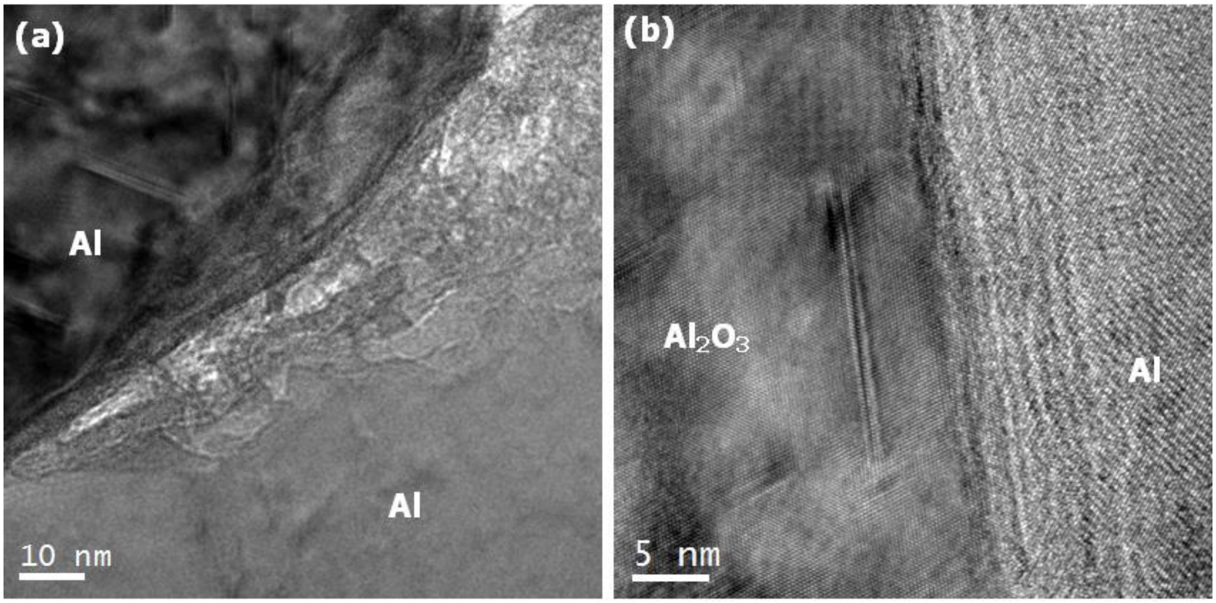

Fig. 1: High-resolution images obtained on Al/Al interface (a) and Al/Al_2O_3interface (b) in the as-prepared sample.

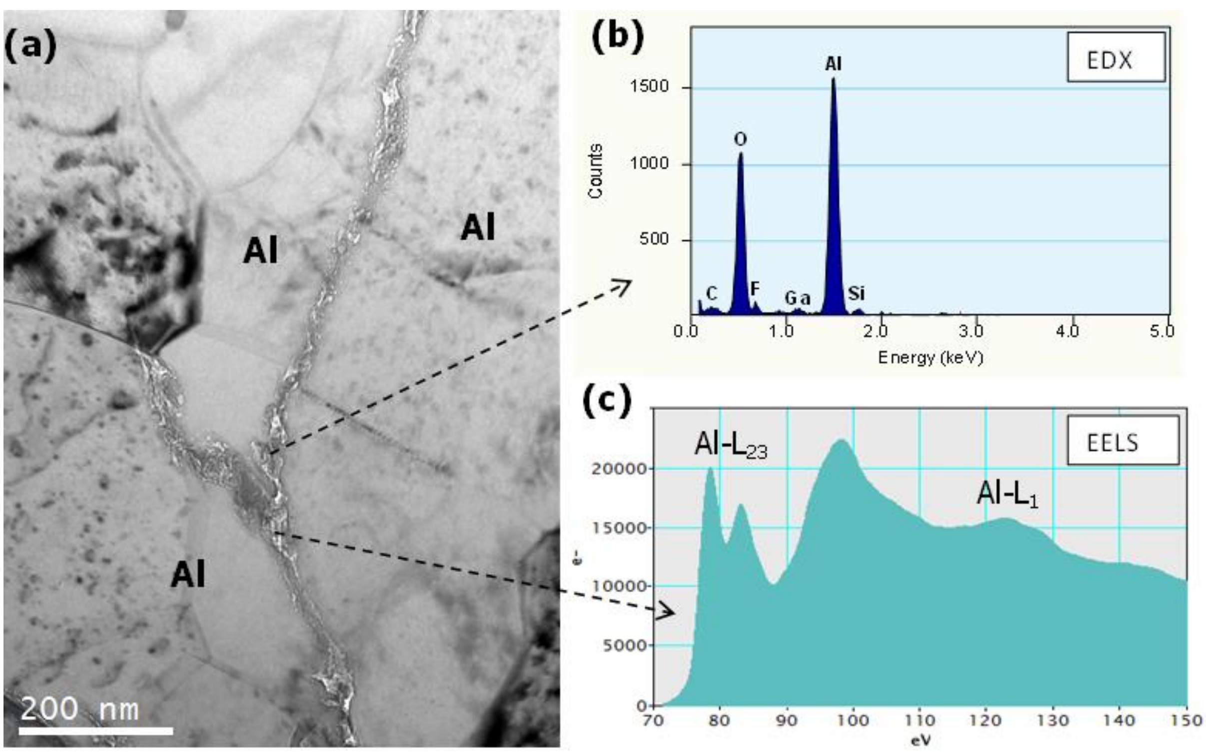

Fig. 2: a) TEM micrograph of corroded Al-Al_2O_3 coating sample showing corrosion product at Al/Al interfaces identified by EDX (b) and EELS (c) as Al_2O_3.