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Meeting-report

The Influence of the Re-Melting on the Microstructure and Corrosion Resistance of New Welding Material

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Introduction

High-entropy alloys (HEA) have gained significant attention in the materials sector due to a new and innovative approach to alloy design. This concept was introduced by Yeh et al. and Cantor et al. [1,2]. HEAs, in contrast to metallic materials, typically contain five or more multi-principal elements, with each constituent element having a concentration ranging from 5 to 35 atomic percent.

Extensive research in this field has revealed that several remarkable works on High Entropy Alloys (HEAs) have shown that alloys with four or fewer multi-principal elements, known as Medium Entropy Alloys (MEA), can display distinctive microstructures and amazing features.

In general, the existing literature has shown that the quaternary AlCrFeNi alloy not only displays the typical characteristics of high-entropy alloys (HEAs), but also possesses outstanding mechanical qualities.

The study showcases novel findings achieved by the application of the GTAW welding technique to clad MEA alloy layers derived from the AlCrFeNi alloy category. The process involved the utilization of a standardized bundle of filler rods, without the need for additional preliminary technological procedures.

In order to enhance the level of chemical homogeneity and enhance the mechanical properties of the weld deposition, an electric arc re-melting process was carried out in the transverse direction with respect to the initial deposition direction, without the use of filler metal.

Experimental

In order to produce the MEA alloy through welding, a group of rods with the same diameter (2.4 mm) was created. This group included an aluminum rod (99.8wt%), a stainless-steel rod (23.1wt% Cr, 8.7wt% Ni, 3.18wt% Mo, and 62.7wt% Fe), and a NiCr rod (64.4wt% Ni and 22.2wt% Cr), as shown in Figure 1.

Upon acquiring the samples that were filled, the deposit was melted again by directing an electric arc over the weld, without the inclusion of additional metal (Sample 1 without remelting, Sample 2 with remelting). The major remelting parameters had the following values: I = 220A, U = 16V, vs = 400 mm/min, Dg = 18 l/min, El = 3168 j/cm.

The microstructure investigation was conducted using the Olympus GX51 optical microscope and the FEI SEM Inspect S scanning electron microscope, equipped with an AMETEC Z2e chemical micro-composition EDS analyzer from the Netherlands.

The specimens were subjected to corrosion testing in a solution containing 3.5% sodium chloride (NaCl) using a Biologic SP-150 potentiostat from Seyssinet-Pariset, France. The EC - Lab® v-9.55 software was utilized to implement the methods and determine the operational parameters.

The EIS test was performed by measuring individual sine waves at frequencies ranging from 10-1 to 105 Hz for both types of samples, following the applicable standard ISO 16773-1-4:2016. Through analysis of the gathered spectra, it was possible to establish a relationship between the chemical and physical characteristics of the synthesized alloys and the continuing electrochemical process.

Results and discussion

Microstructure

Figure 2 shows the fusion line, which is the boundary between the welded deposit and the heat affected zone of the unalloyed steel substrate material, in sample 1. Within the weld deposit, an area above the fusion line was identified where complete mixing of the base material with the filler material was not achieved. This region contains grains that have developed from the limits of the substrate material. The weld deposit at the top of the photograph displays visible intermetallic compounds, with white compounds being rich in Nb and black compounds being rich in Al.

Figure 3 illustrates sample 2, where it is obvious that the fusion line is continuous and with very good adhesion between the deposited material and the substrate. The weld deposit contains phases rich in aluminum and intermetallic compounds rich in niobium and molybdenum.

Electrochemical Impedance Spectroscopy

To determining the properties of the samples, the impedance data will be utilized. After doing an analysis of the Nyquist plots (refer to Figure 4a), it becomes evident that every sample possesses two distinct zones that can be distinguished from one another [3]. A zone that is defined by low impedances at high frequencies is referred to as the first region, while the second region is a part of a zone that is characterized by medium and high impedances. This pattern makes it abundantly clear that there is at least one activity that is dependent on frequency that is contributing to the feedback [4].

The impedance spectra for both samples reveal overlapping curves at high frequencies in the Bode-IZI plots (see to Figure 4b and 4c for more information). These curves indicate the electrolyte resistance, which is the same for both samples. The low-frequency zone corresponds to the total impedance of the passive film and electrolyte. If the ultimate resistance remains constant in all samples, any variations found in the low-frequency band can be ascribed to alterations in the film. The presence of conductive channels within the film may be responsible for these alterations. The low-frequency impedance of sample 1 exhibited a tenfold drop compared to sample 2, suggesting a ten times lower corrosion resistance of the coating.

Conclusions

In the current study, coatings of Medium Entropy Alloys (MEA) from the AlCrFeNi class were laser cladded on an unalloyed steel substrate. Following this, electric arc re-melting without filler metal was carried out in the transverse direction in relation to the direction in which the initial deposition was carried out. There was almost a tenfold increase in the corrosion resistance of the sample that had been re-melted in comparison to the sample that had not been re-melted.

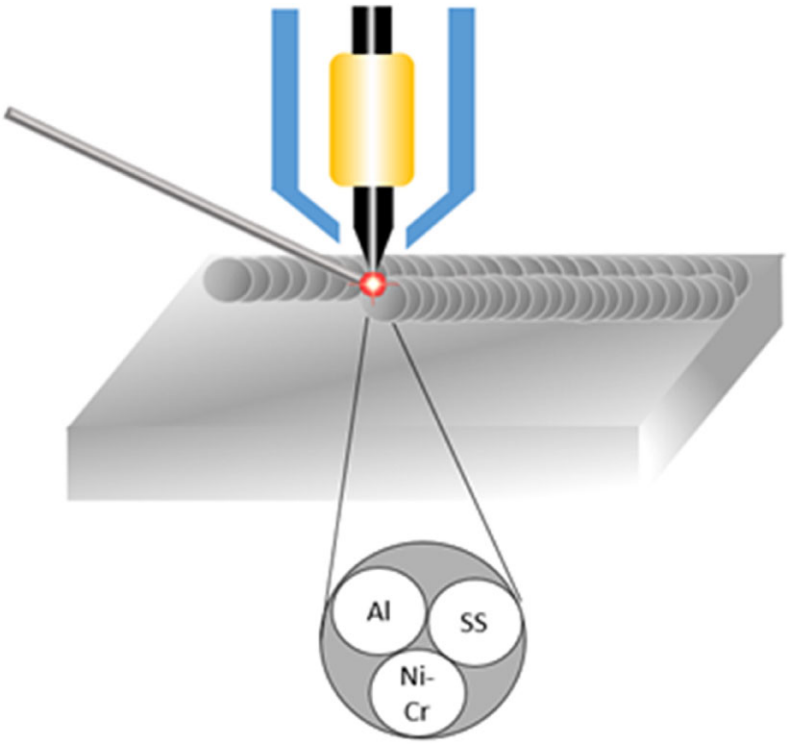

Fig. 1. The filler metals bundle and the welding process.

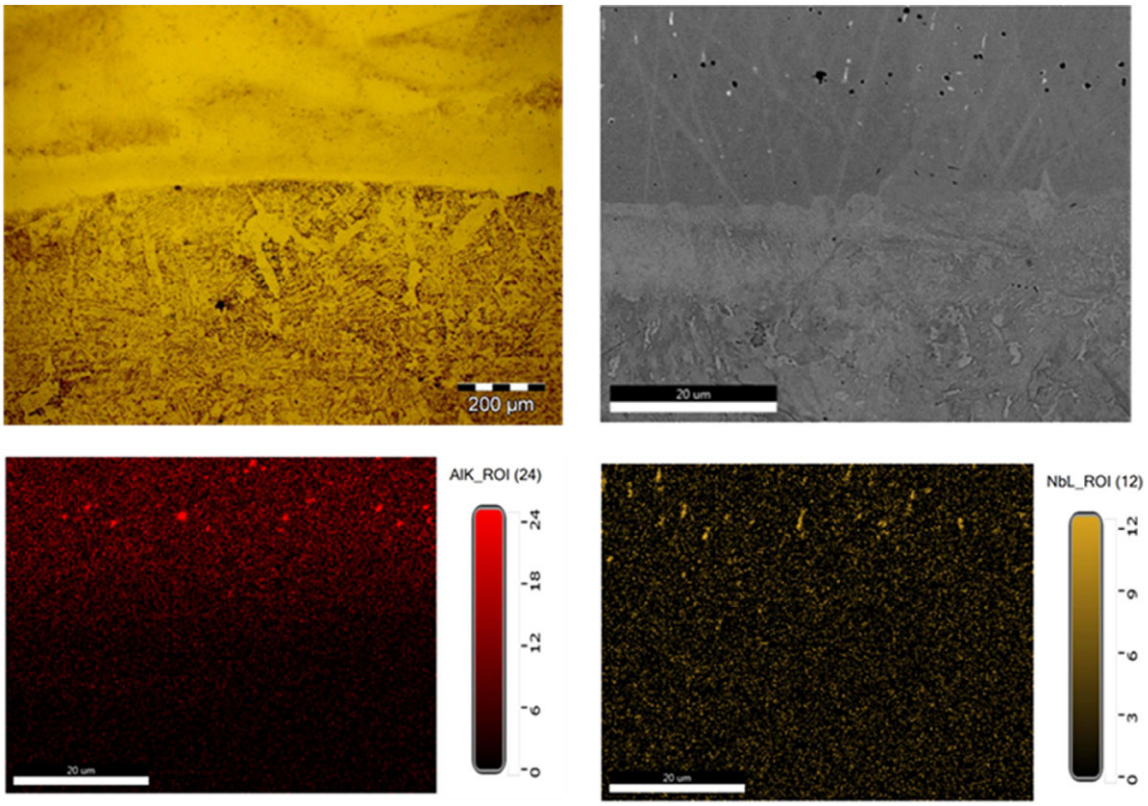

Fig. 2. Optical and SEM image together with elemental maps for Sample 1.

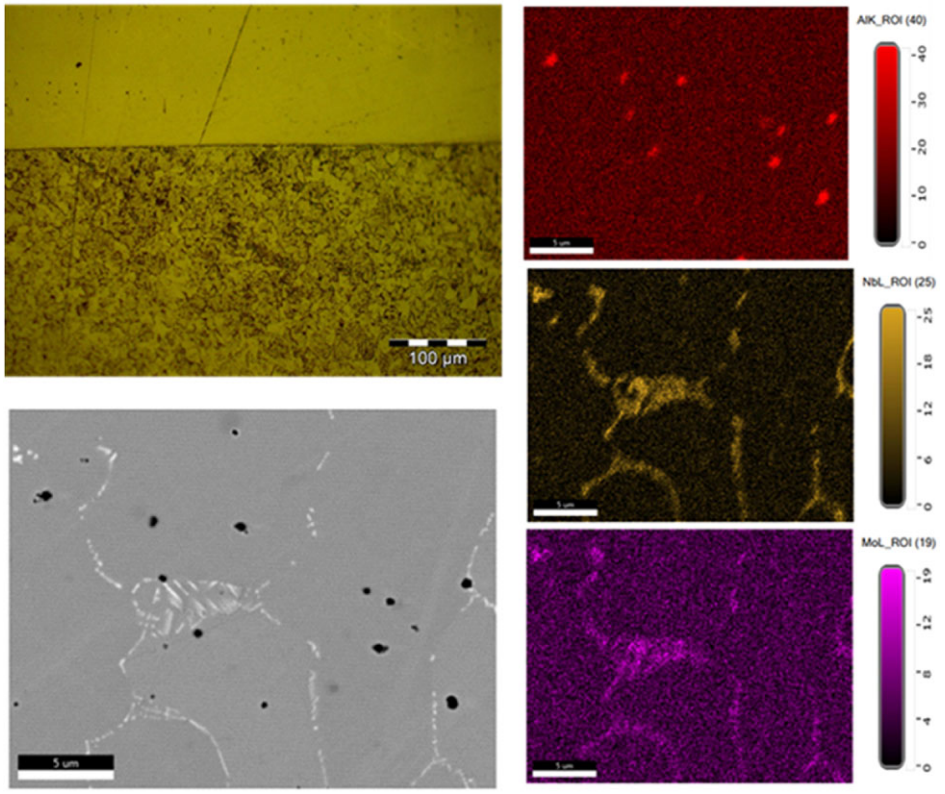

Fig. 3. Optical and SEM image together with elemental maps for Sample 2.

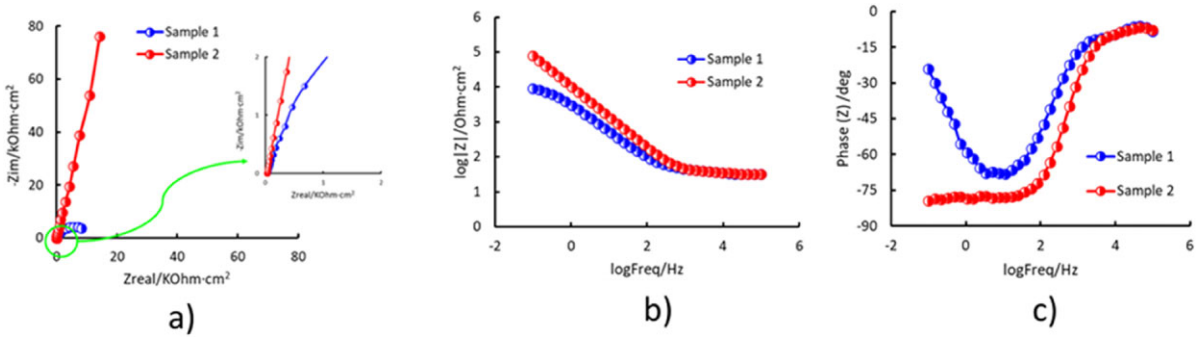

Fig. 4. a) Nyquist plots; b) Bode-IZI and c) Bode-phase for the two samples at corrosion potential in 3.5%NaCl.

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