International Journal of Modern Manufacturing Technologies
ISSN 2067–3604, Vol. XIV, No. 3 / 2022
https://doi.org/ 10.54684/ijmmt.2022.14.3.16

THIN NICKEL LAYER BEHAVIOUR IN NATURAL SEA WATER

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Abstract: Various methods were used, in order to protect the material base; the study subject has been put under various conditions and were thus implemented in an attempt to prolong the operating life and to require less maintenance and replacement of parts. Pulsed laser deposition method was used to cover a S 235 carbon steel sample with a thin nickel film, using laser ablation and thus obtaining a protective layer, offering increased corrosion resistance. S 235 carbon steel samples were covered on a single face with thin films. The material used for laser ablation is nickel. The samples were immersed for 126 days in static seawater at ambient temperature and were individually weighted on the analytic balance at different time intervals, in order to determine the corrosion process speed. The study was performed by employing the gravimetric method. Through the corrosion research process using the gravimetric method, the parallelepiped samples covered with Ni using pulsed laser deposition were immersed 126 days in static sea water at environment temperature. The corroded surfaces, after being submerged in seawater, were investigated using optical microscopy and atomic force microscopy. Atomic force microscopy investigations performed on long-term corrosion-tested samples highlight areas with compact and homogeneous surfaces that did not allow the corrosive agent to interact with the base material, a fact confirmed by optical metallographic analysis. Wave mode images show discontinuities of surface-deposited incipient corrosion points that are possible pathways of the corrosive agent to the sample material. The analysis made on one side thin film covered sample, after a long term corrosion test, using atomic force microscopy investigation and gravimetric test, shows the rate of corrosion, the discontinuities of the surface and the corrosion pitting in the material. Evaluating the method of thin film deposition layer leads to the obtainment of high reliability and low cost material parts using this method. The corrosion rate is established, remains constant and protection of the material base is achieved.

Key words: nikel thin layer, sea water, atomic force microscopy, corossion rate, corrosive agent.

1. INTRODUCTION

Pulsed Laser Deposition (PLD) is just a collection of thin film physical vapours deposition (PVD) techniques. This technique enables, during the transfer of material from the target to the substrate, the preservation of stoichiometry, offering at the same time, flexibility and control over the deposition rate. Using the pulsed laser deposition method, any compound existing in nature or made with the help of a theoretical model can be obtained. Thus, deposits of superconducting materials (Villanueva, 2006), metals, semiconductors and dielectrics, piezoelectric, ferroelectric materials, nitrides and carbides, oxide binary or tertiary compounds, polymers, etc. have been reported as achievable (Barankova et al., 1997).
Plasma atoms and ions have sufficient kinetic energy to ensure a high adhesion coefficient, surface mobility and thin film nucleation, thus they do not need to use very high temperatures to heat the substrate. When the target absorbs the laser pulse, the energy, in the first phase, is converted into electronic excitation. Then, this electronic excitation results in thermal/chemical/mechanical energy. Finally, this process results in evaporation/ablation/plasma formation and can even lead to exfoliation.
The marine environment is recognized as the most corrosive natural environment. Nickel-containing materials such as copper-nickel alloys, stainless steels and nickel-base alloys have been found to provide optimum techno-economic solutions in corrosive natural environment (Brian, 1986). As mentioned in various literatures (Barry and Sharon, 1980; Kear et al. 2004, Mohan and Rajasekaran, 2015), it is well-known that the corrosion of Cu-Ni alloys in seawater is a typical electrochemical corrosion is due to the high chloride ion content (around 19%) in seawater,

when the Cu-Ni alloy has low anodic polarization and a high corrosion rate in the process of corrosion (Tingzhu, 2019).
The paper presents research dedicated to improving the corrosion resistance of carbon steels by utilizing the process of thin film deposition using pulsed laser deposition. The results represent a technological advancement that leads to high reliability and low costs for most metal parts (Barhalescu, 2007).
This paper aims to report the corrosion in sea water behaviour of carbon steel coated with Ni by pulsed laser deposition, to understand the effect of Ni on increasing the corrosion resistance of carbon steel and to study the corrosion of these new superficial layers (Alharthi et al., 2017).

2. EXPERIMENTAL METHOD AND MATERIAL

For this experimental research, S 235 carbon steel was used as a sample, for the study of superficial deposition using pulsed laser deposition. On S 235 carbon steel samples, with dimensions of 2x20x20 mm, a single face was covered with thin films. The material used for laser ablation is nickel. The samples were immersed in static seawater for 126 days, at environment temperature. They were individually weighted on the analytic scale at different time intervals. This allowed the determination of the corrosion process speed ((Barhalescu, 2007).
These were used to see the influence on corrosion resistance in sea water for superficial layers (Sherif et al., 2016, Chirsey and Hubler, 1994).
PLD is a thin-film deposition technique using high-energy laser pulses to vaporize the surface of a solid target inside a vacuum chamber. In order to form a thin film up to a few micrometres in thickness, the vapours are condensing on a substrate. Figure 1 shows a schematic diagram of a typical PLD process.

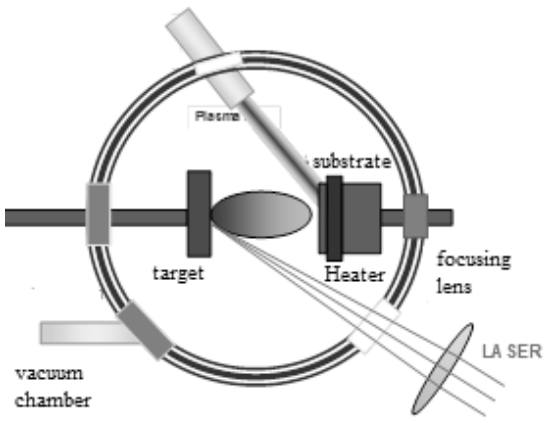

Fig. 1. Schematic diagram of a typical laser deposition

To the best of the Authors' knowledge, the corrosion behaviour of Ni-coated carbon steel using pulsed laser deposition in seawater has not been previously reported in the literature (Kim et al., 2005; Konishi et al. 2005; Bai et al., 2003). The study was performed by gravimetric method. The corrosion research process, which involves the use of the gravimetric method, is stated as follows: the parallelepiped samples covered with Ni using pulsed laser deposition, with the surface of 0.00127512 m^2, were suspended with an synthetic line (nylon) in a plastic material tub at 4 cm above the tubes' liquid level (seawater), being immersed 126 days in static seawater at normal environmental temperature (Huang et al., 2004; Allahkaram et al. 2011). The corroded surfaces, after being submerged in seawater for 126 days, were investigated using optical microscopy by employing the computers QX3 Intel Play microscope and atomic force microscopy (Ashassi, 2004). It was expected that the samples obtained through deposition of Ni film on carbon steel would show better corrosion resistance than base steel, with Ni protecting them from being easily corroded (Wharton, 2005).

3. RESULTS AND DISCUSSION

Short-term gravimetric corrosion tests are not accurate enough and are less relevant than long-term corrosion tests.
During the long immersion of the samples in seawater, the exposed surface undergoes changes, in the sense that it suffers perforation of the deposited surface layer. Furthermore, there is corrosion in points (very small areas) following the penetration of the corrosive agent.
The variation of the corrosion speed results from immersed samples in seawater (126 days) and is presented in figure 2.

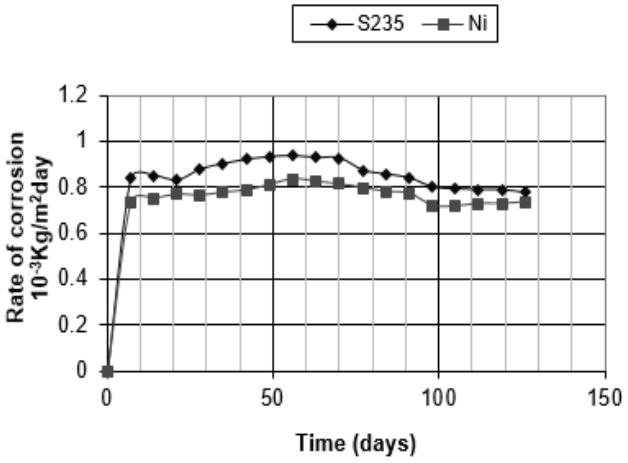

Fig. 2. Rate of corrosion

The metallographic analysis was performed on the surface of the samples after they were removed from the environment, washed and cleaned of corrosion.
Figures 3 to 6 show the optical metallographic analysis of the S 235 steel samples coated with a thin nickel film by laser ablation.
From the optical metallographic analysis of the carbon steel sample on which the thin Ni film was deposited by laser ablation (figure 3), the generalized corrosive attack on the edges of the deposited surface is observed, these areas being susceptible to corrosion in the layer.

Figure 4 shows an area of the deposited Ni layer in which the very rapid appearance of corrosion pits in the presence of seawater is evident.
Exfoliation of the deposited layer in a relatively short time of exposure to seawater is highlighted in figures 5 and 6, a possible reason for this exfoliation being the presence of conglomerates in these areas of the sample that affect the quality of the deposited film.
The corrosion resistance should be noted when applying the film on one side, the most attacked areas of the sample being the edges of the deposited surface.

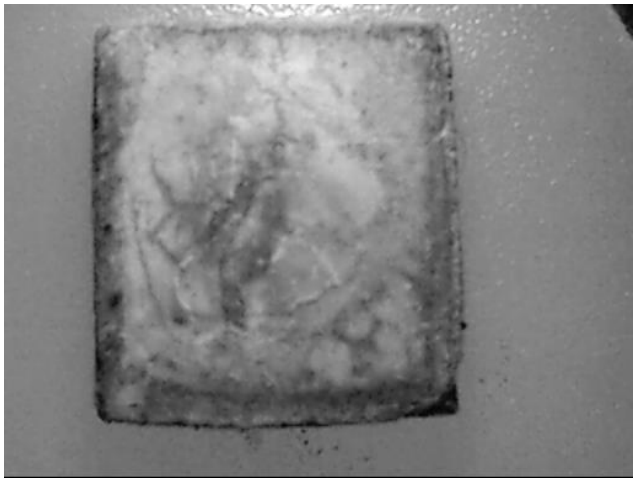
Fig. 3. S235 steel sample covered with thin Ni film – 30:1

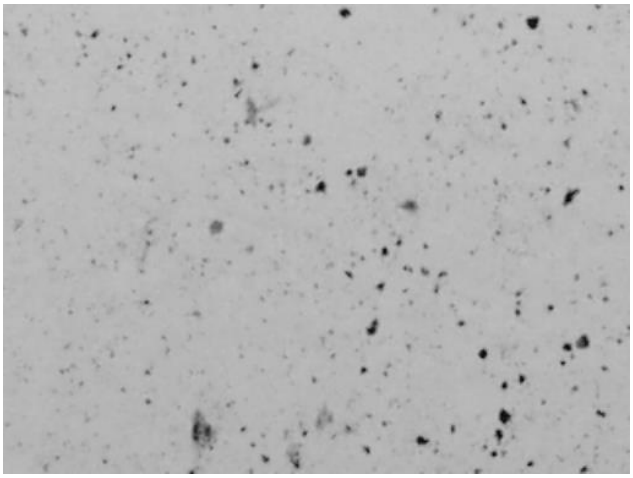
Fig. 4. S235 steel sample covered with thin Ni film – 60:1

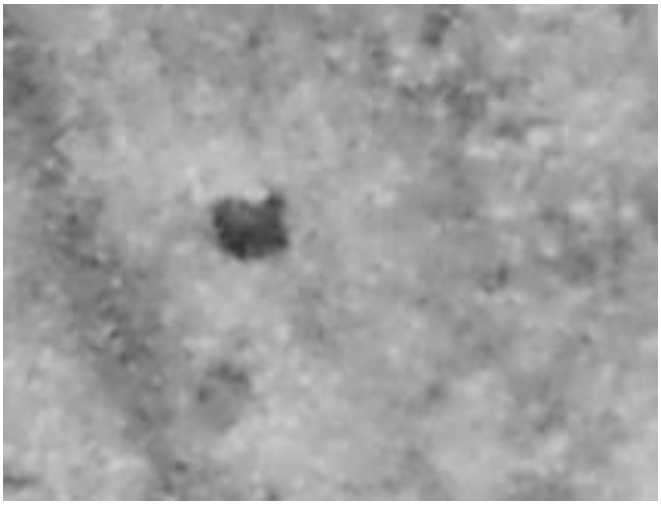
Fig. 5. S235 steel sample covered with thin Ni film – 60:1

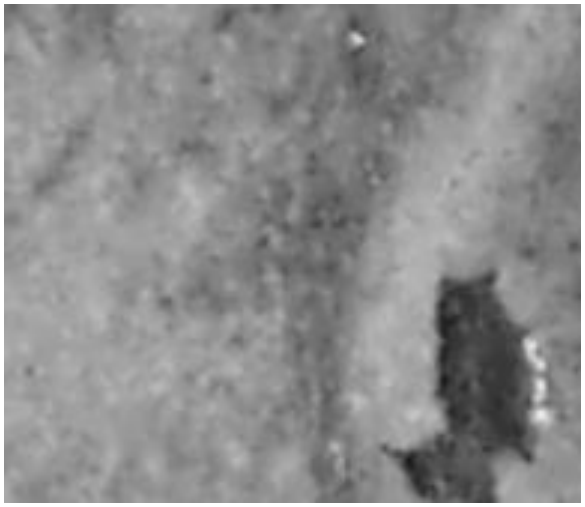
Fig. 6. S235 steel sample covered with thin Ni film – 60:1

The AFM - wave mode images on the layers illustrated in figures 7, 8 and 9 show the existence of compact islands and formations in the deposited material.
The three-dimensional presentation in Figure 8 attests to the appearance of dark areas that represent points with the lowest height, the difference between the lowest and highest areas reaching the value of 1.601 μm.
The relief surface histogram covered with a Ni film (Figure 9) shows the average value of the measurements on the sample profile which reaches the value of 886.9 nm, which indicates a non-uniformity of the deposited layer, and the possibility of corrosive agent penetration to the base material.

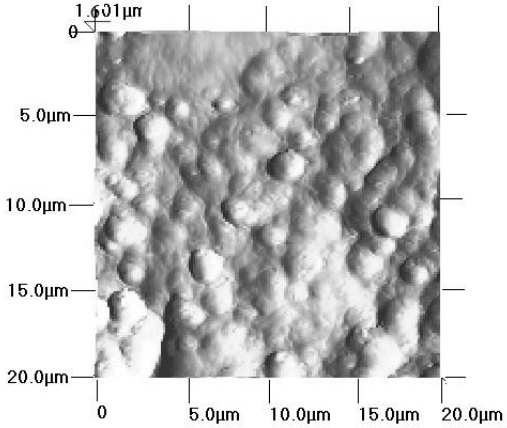

Fig. 7. S235 steel sample covered with thin Ni film - 2d wave mode image on a scanned area of 20x20µm

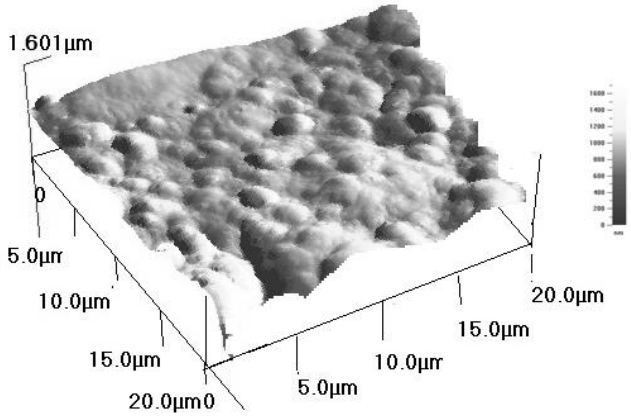

Fig. 8. S235 steel sample covered with thin Ni film -wave mode -3d image on the same scanned area

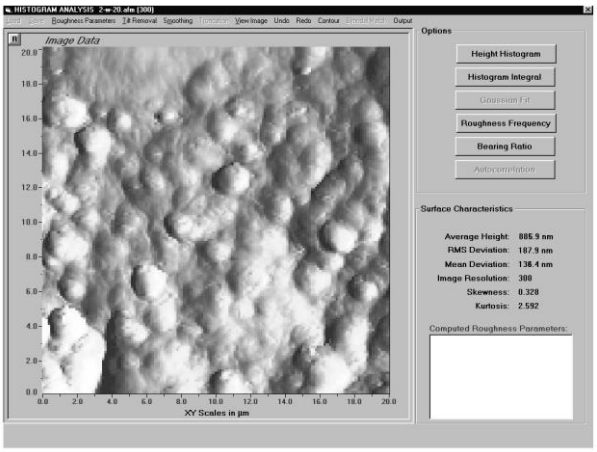

Fig. 9. Histogram of heights on the surface profile sample covered with a Ni film

4. CONCLUSIONS

Corrosion behaviour of Ni superficial layer deposited on S 235 carbon steel immersed in seawater for 126 days were investigated using gravimetric corrosion tests, optical metallographic analysis and Atomic force microscopy investigations. According to the results, the following conclusions can be summarized:

1.The deposited surface layer provides an increased corrosion resistance in seawater compared to the base steel, especially in long-term tests, when the corrosion rate is established and remains practically constant.

2.From the optical metallographic analysis of the thin films obtained by the PLD method, on one side of the samples, a pronounced corrosive attack on the edges of the deposited surface is found.

3.Structural investigations by optical microscopy have revealed the appearance of pitting corrosion which, once initiated, can propagate and form in the depth of the material in the form of holes. The characteristics of the environment in which the experiments were performed are elements that accelerate and support pitting and layer boundary corrosion (presence of chlorine ions).

4.Corrosion advances below the deposited layer and generates its detachment from the base material

5.Atomic force microscopy investigations performed on long-term corrosion-tested samples highlight areas with compact and homogeneous surfaces that did not allow the corrosive agent to interact with the base material, a fact confirmed by optical metallographic analysis. Wave mode images show discontinuities of surface-deposited starts, which are possible pathways of the corrosive agent to the sample material.

6.The presence of pitting corrosion on the surface of the deposited film by the PLD method shows its vulnerability to the corrosive agent. Microalloying of the deposited material with the impurities existing in the base material allows the initiation of pitting corrosion in the presence of chlorine ions.

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Received: March 21, 2022 / Accepted: December 15, 2022 / Paper available online: December 20, 2022 © International Journal of Modern Manufacturing Technologies