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Physical properties of the TiN coating deposited on the X6CrNiTi18-10 steel base in the PVD process

S. Topolska, D. Szewieczek

Division of Quality Management, Institute of Engineering Materials and Biomaterials, Silesian Technical University, 18A Konarskiego Str., 44-100 Gliwice, Poland

The paper presents results of the analysis of the utilization the TiN coatings deposited on the base of an austenitic steel in the electrochemical processes.

1. INTRODUCTION

The depositing of the coatings in the PVD (Physical Vapour Deposition) processes often leads to obtain new or better properties of the surface layer of the universally applied materials. Coatings obtained in the PVD processes are more and more applied nowadays. Among others they let to improve significant the properties of the tool materials coated with them. For example the tools coated with the coatings basing on the carbides, nitrides, borides and oxides could work at higher work parameters [1].

Simultaneously the trials are made to apply the surface layers basing on the TiN that have been deposited in the PVD process on the steel bases in the electrochemical processes in which the main or secondary reaction is the cathode process of a hydrogen evolution [2, 3].

For example, the rules of the environment protection lead to elimination of the mercury installations, applied for the chlorine production. They require to implement the installations of new generation in which are applied the solid cathodes [4, 5]. It is consider with the possibility of manufacturing the electrodes that are coated with a coating of a low overpotential of hydrogen evolution [6, 7].

The facts, mentioned above, caused the aim of the work has been the determination of the influence of the TiN surface layer coated on the base of the X6CrNiTi18-10 steel on properties of such manufactured electrode. The coating has been deposited in the process of magnetron sputtering.

2. RESULTS AND DISCUSSION

Coatings are deposited on the base of the X6CrNiTi18-10 steel. Its chemical constitution is as below (mass fraction in %): C – 0,08%, Mn – 2,00%, Si – 1,00%, P – 0,045%, S – 0,015%, Cr – 18,5%, Ni – 10,5%, Ti – 0,6%.

The TiN coating has been deposited on the conventionally prepared surface of a specimen (length l = 30 mm, diameter ø = 5,00 mm). It been deposited in the process of magnetron sputtering, using the magnetron disc made of a pure titanium which is the source of the ions of a metal that react with the gas introduced to the installation chamber (N_2). The conditions have been as follows: power – 603 W, reacting gas N_2 – 27%, base temperature – 320 ^{o}C.

For such a specimen the next tests has been done:

- surface morphology and specimen structure, in the XL-30 scanning electron microscope using the voltage of 20 kV and magnifications of 400x – 10000x,
- investigations of physical properties:
  - determination of the polarization curves of the hydrogen evolution process,
  - determination of the capacitance of the double layer,
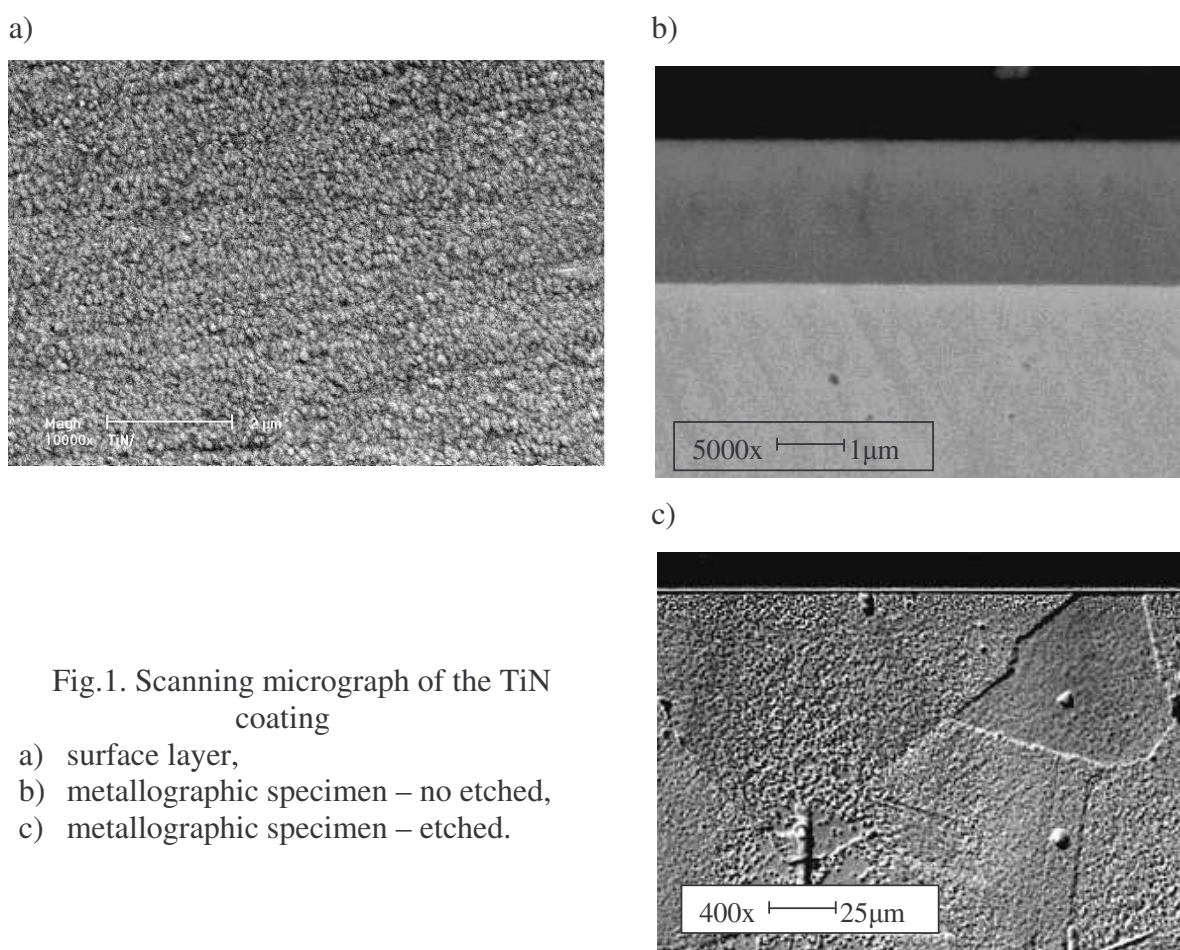 - determination of the corrosion resistance.

a)

b)

c)

Fig.1. Scanning micrograph of the TiN coating
a) surface layer,
b) metallographic specimen – no etched,
c) metallographic specimen – etched.

As a result of the conducted metallographic investigations it has been stated that the TiN coating is homogeneous. Its surface consists of elementary particles of the size from 35 nm to 120 nm that are located one by one (Fig.1a). The obtained TiN layer deposited on the steel base of an austenitic structure is 2,0 μm thick (Fig.1b,c).

It has been used three chambers, glass electrolyser to determine the polarization curves of the hydrogen evolution (described as the function E=f(logj)). It has been equipped with the

water jacket joined with the E1B2 ultrathermostat. The apparatus also consist of the PSG 201T potentiostat with the IMT1 program. The measurements have been conducted in the temperature 25 $^{\circ}$C, in the basic (-2600mV ÷ -1000mV) and inert (-2200mV ÷ -1000mV) medium (regarding NEK).

The values of the "a" and "b" coefficients of the Tafel equation ($\eta=a\pm blogj$) that determine the value of the overpotential of the hydrogen evolution in the investigated medium have obtained the next values (Fig.2 and 3):

- the 1M NaOH medium – -a = 427mV, -b = 212mV,
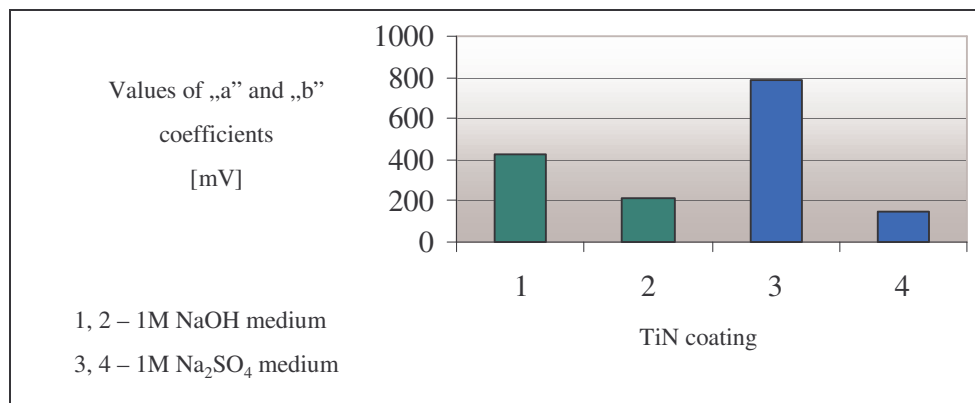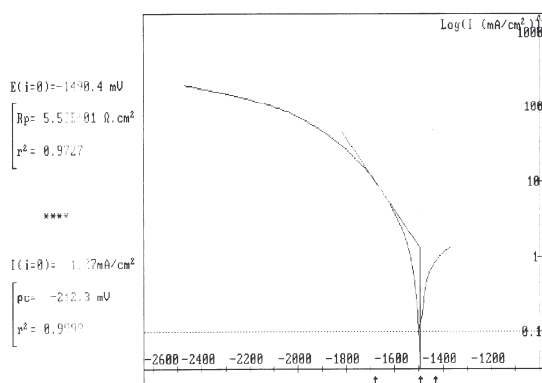- the 1M Na_2SO_4 medium – -a = 789mV, -b = 147mV.

Fig.2 The graphical representation of values of the "a" and "b" coefficients of the Tafel equation

As one can see the value of an overpotential of the investigated TiN coating is lower in the basic medium in comparison to the inert one.
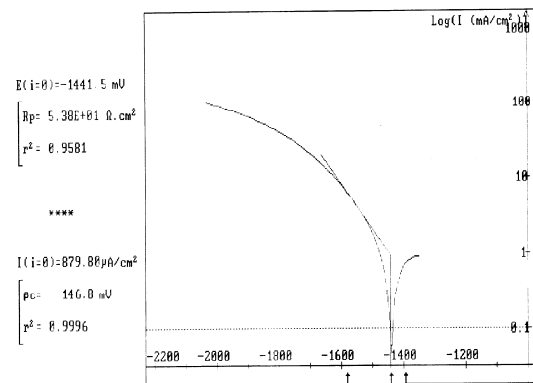

Fig.3. The relationship between the hydrogen evolution potential I [mA/cm^2] and the electrode potential E [mV] of the TiN coating for: a) the basic medium, b) inert medium

Basing on a measurement of a differential capacitance of the double layer conducted in the glass electrolyser with the equipment (Fig.4), in the 5M NaCl medium (-500 ÷ -900mV) regarding NEK, in the temperature of 25 $^{\circ}$C it has been stated that at the beginning of the process the value of the capacitance increases at first 11 cycles and then stabilizes. The investigated TiN coating characterizes a not large value of the capacitance of a double layer (80,2µF/cm^2), what results in the next level of the active surface development: 4,718.
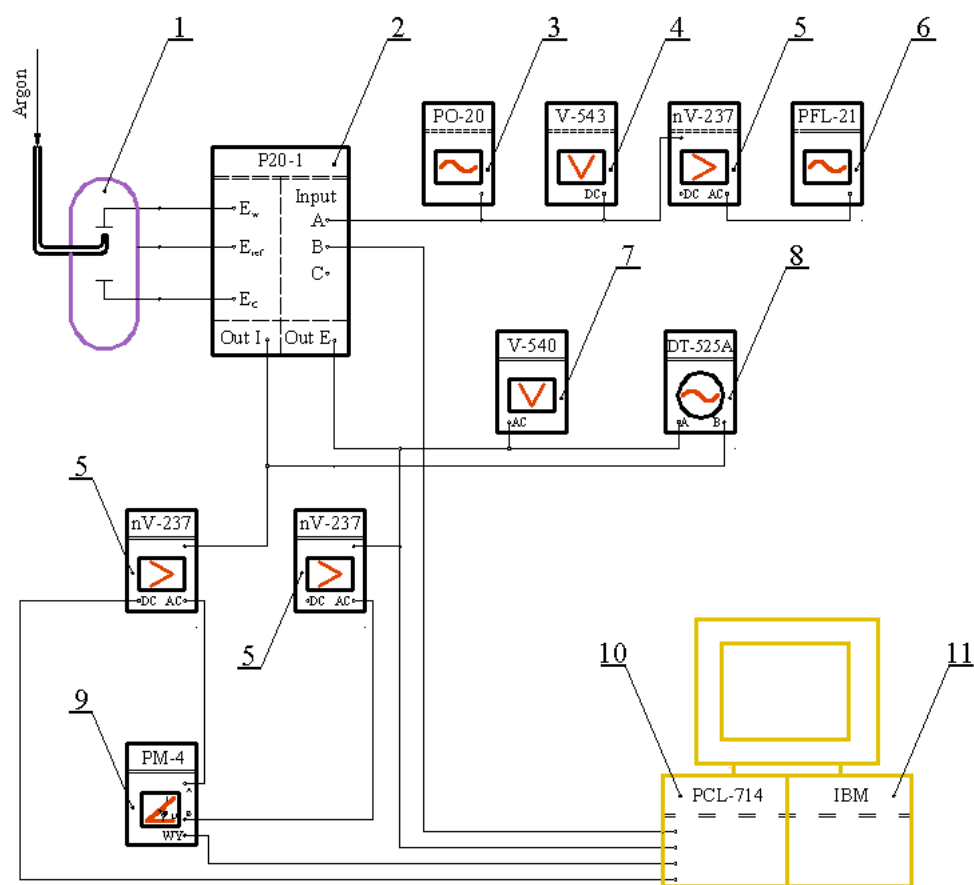
Fig.4 The scheme of the apparatus for determining the differential capacitance of the double layer of an electrode: 1 – electrolyser, 2 – potentiostat (P20-1), 3 – sinusoidal oscillator (Po-20), 4 – digital voltmeter AC (V-543), 5 – selective nanovoltmeter (UNIPAN-237), 6 – frequency meter (PLF-21), 7 – digital voltmeter DC (V-540), 8 – two-channel oscilloscope (DT-525A), 9 – meter of the phase shift angle (PM-4A), 10 – AD/AC converter (PCL-714), 11 - computer

To determine the values of a corrosion resistance of the TiN coating it has been used the Stern-Tafel method with the VotaLab^{TM}21 system and the voltammetric method (i = f(E)). The investigations have been conducted in the two-chamber electrolyser, in the inert and basic medium (like in the case of determining the overpotential) in the room temperature (reg. NEK).

The conducted investigations shows that the coating characterizes with the high corrosion resistance, both in the basic medium and in the inert one. This resistance is suitable equal to 0,006mm/year i 0,008mm/year. The corrosion coefficient of the investigated coating is similar in both media. But for the base steel (the corrosion-resisting steel) the corrosion coefficient is completely different. In the inert medium the corrosion coefficient is 15 times larger then the coefficient for the coating, and in the basic one – 30 times (Fig.5).
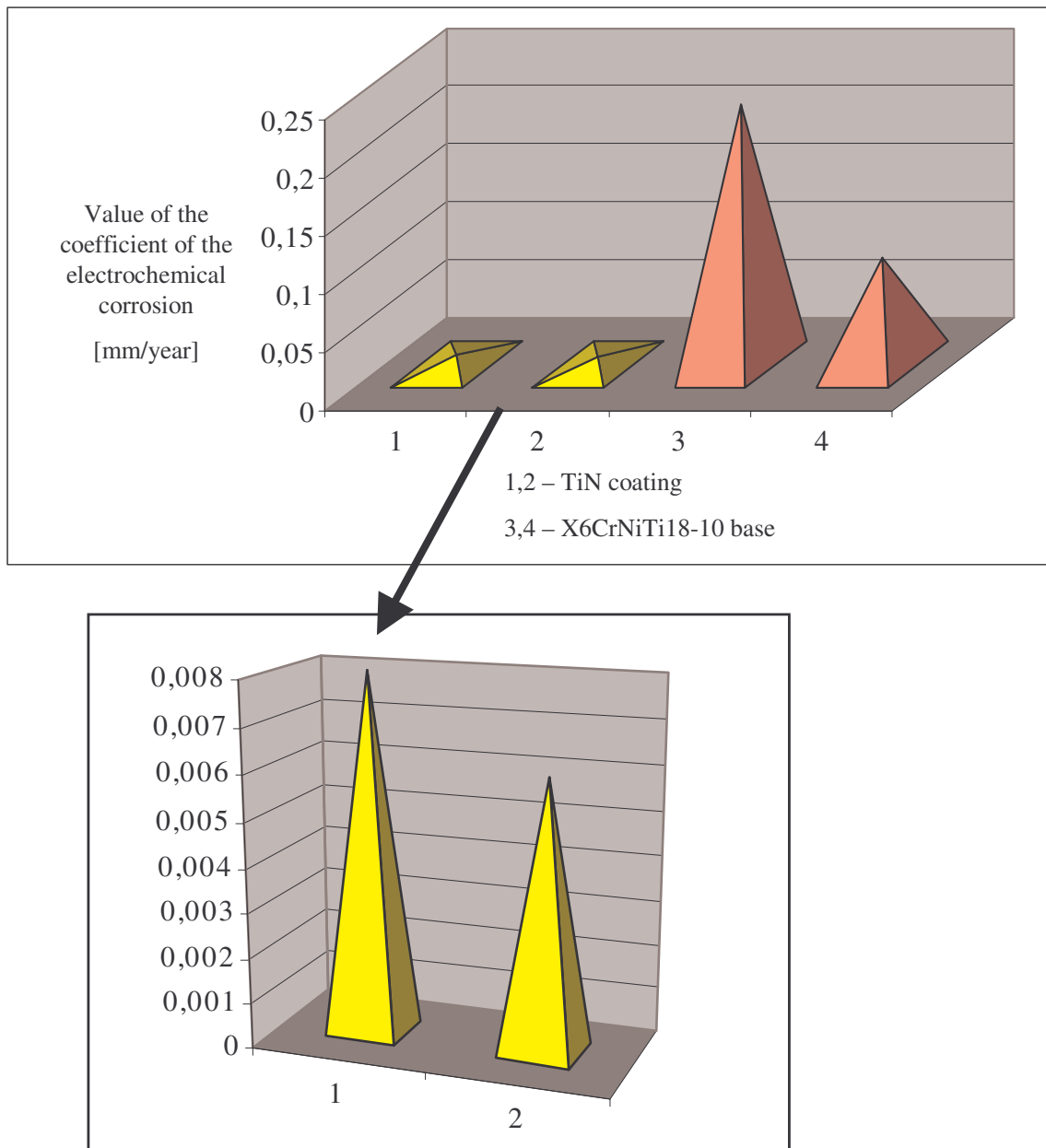
Fig. 5. The coefficient of an electrochemical corrosion [mm/year] for the coating and base

3. CONCLUSION

Concluding the TiN coating obtained in the PVD process on the base of the austenitic steel (X6CrNiTi18-10) characterizes by the homogenous morphology of the surface. This coating is a "compact" coating so it shows a low level of active surface development. Hence, in spite of this the values of the "a" and "b" coefficients of the Tafel equation are not too high.

In spite of the fact that the coating is not too thick (about 2 µm) it shows a very high corrosion resistance. It is about 15 – 30 times higher then the corrosion resistance for the austenitic steel which is corrosion resistant. The resistance is higher for the inert medium.

This is why, in a dependence of the required corrosion resistance, the trials are made to apply the coatings of titanium nitride deposited using the PVD method. These coatings are utilized as surface layer of cathodes which are applied in the electrochemical processes. In these processes the base or secondary reaction is the cathode process of a hydrogen evolution.

The next investigations will prove our assumptions only when it is finished the special tests in a form of electrolytic processes.

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