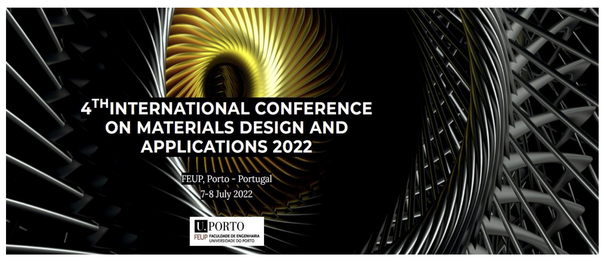

ELECTROCHEMICAL EVALUATION OF MAGNETRON SPUTTERING THIN-FILMS TO PREVENT HYDROGEN DAMAGE IN STEEL SUBSTRATES

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INTRODUCTION

- It is important to understand the capability of thin-films barriers deposited by High Power Impulse Magnetron Sputtering (HIPIMS).
- Titanium Nitride (TiN) thin film is deposited by magnetron sputtering on carbon steel (CS) substrates to mitigate the hydrogen permeation (Figure 1).
- The aim of this work consists of identifying the effectiveness of TiN (Titanium Nitride) by HIPIMS magnetron sputtering thin-film barriers, in reducing the hydrogen permeation [1] on the carbon steel substrate material, through the ISO 17081 method of measurement [2].
- Hydrogen management relies on barrier technology to decrease the concentration gradients.

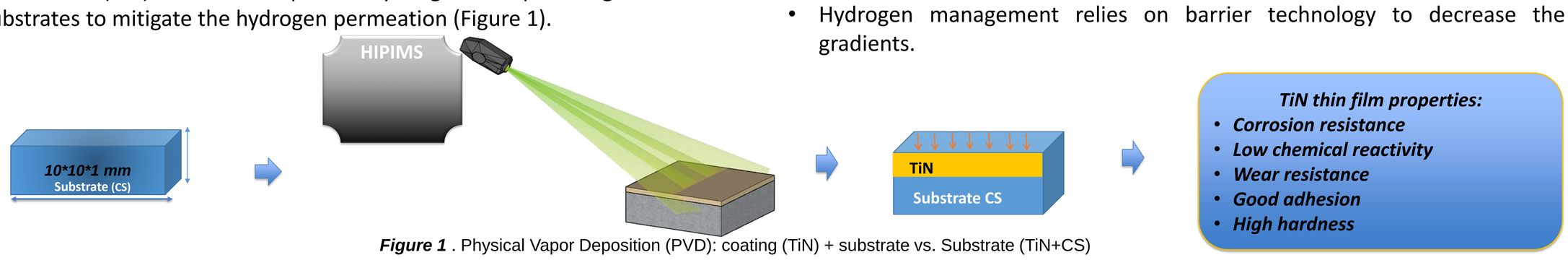

Figure 1 . Physical Vapor Deposition (PVD): coating (TiN) + substrate vs. Substrate (TiN+CS)

EXPERIMENTS

The experimental evaluation was developed in Devanathan–Stachurski cell to measure electrochemical hydrogen permeation (Figure 2) [3] .

The diffusion of hydrogen inside the sample is consistent with Fick's law, equation 1.The diffusion theory shows that the relationship between diffusion coefficient D of the atom and diffusion temperature T is consistent with the Arrhenius equation , [4] :

$$J = -D\frac{dC}{dx}\ Eq\ 1$$

$$D = D_0 \exp\left(-\frac{Q}{RT}\right)\ Eq\ 2$$

D = Diffusion coefficient (m^2/seg) (Daap)

D_0 = Constant (m^2/seg)

Q = Activation energy (J/mol; cal/mol)

R = Cte. Molar gas=1,987 cal/mol·K

J = Hydrogen Flux

dc/dx = Hydrogen concentration gradient

Table1*: Controlling Parameters TiN +CS*

Variable	Symbol	Data	Units
Charge Area	Ac	1.2469	cm2
Sensing Area	As	1.0383	cm2
Thickness	L	0.97	mm
Charging current	Ic	9.092	mA
Density of I charge	Ic'	7.29168337	mA/cm2
Charge start time	t0	3665.5	seg
Start current	I0	-5.3778E-07	A
Limit current	Isat	0.02153219	mA/cm2
Time lag(Dperm)	tl	2.7512E-10	m2/s

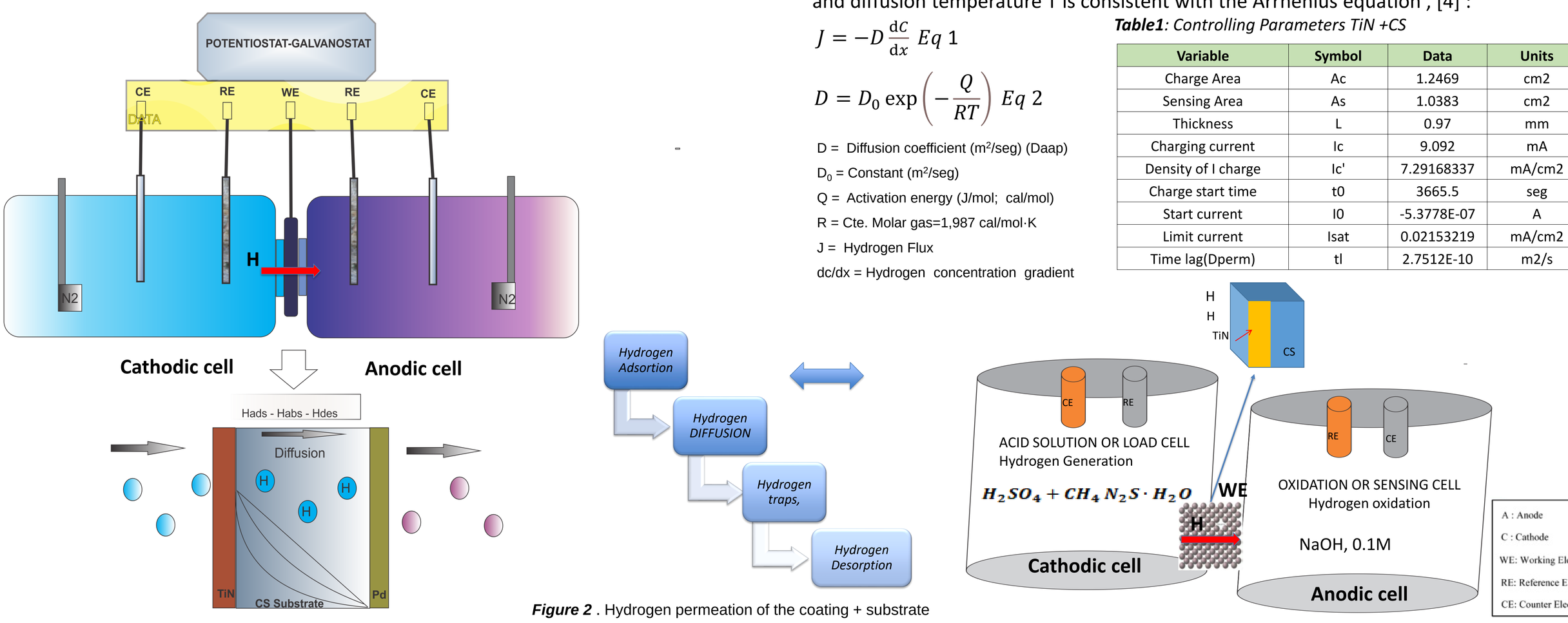

Figure 2 . Hydrogen permeation of the coating + substrate

RESULTS

- This study confirmed that TiN coating was dense and effectively served as hydrogen barriers. When compared at a test temperature (27° C), the hydrogen permeabilities curves of the TiN-coated samples smaller than of the uncoated substrate, respectively. Typical diffusion curves are illustrated in Figure 3.
- The criteria to determine if the barriers decreased the of hydrogen into the metal were the stability current and the penetration time.
- The stability current in carbon steel was around 50 uA/cm2 while said current in the three barriers evaluated was less than 20 uA/cm2.
- The penetration time of hydrogen was higher in the samples with the barrier (TiN) applied compared to the penetration time of carbon steel.
- A strong reduction in the hydrogen permeating the metal is evident in TiN barrier.

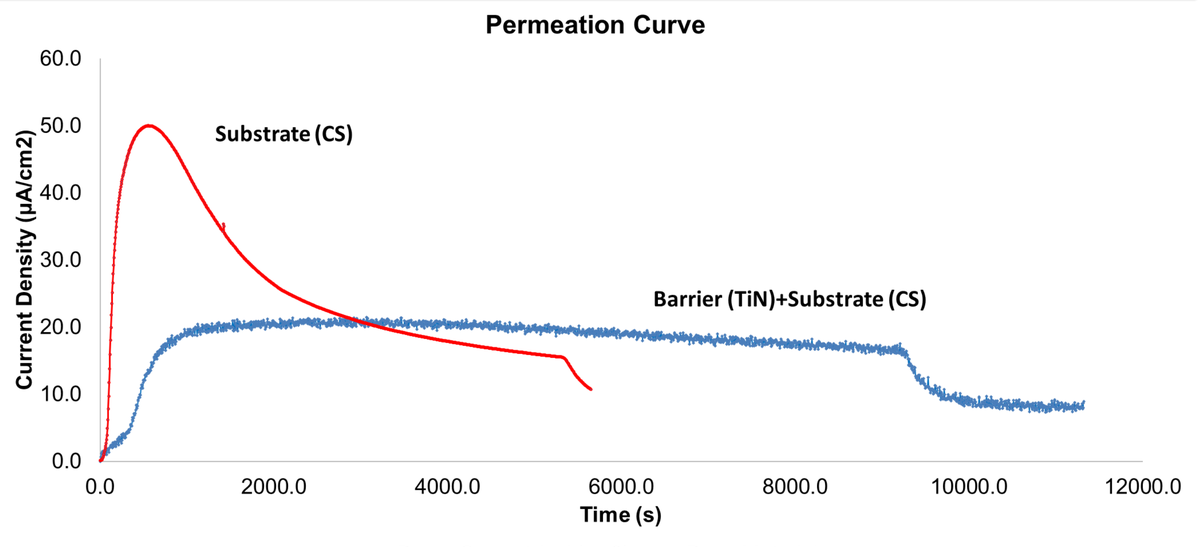

Figure 3 . Hydrogen permeation results of the coating + substrate vs. substrate

CONCLUSIONS

- The importance of this study was to identify the effectiveness of barriers in reducing or delaying the hydrogen flow to the substrate material, through the coating permeation by electrochemical permeation curve (current density – I (t) vs time - t).
- The major findings in this work were that permeation curves have a tendency of low hydrogen permeation in the time for the coating TiN evaluated, according to the Figure 2.
- The HIPIMS deposition of a TiN thin film onto carbon steel apparently served as a barrier to hydrogen permeation into substrate.
- For evaluating the suitability and in-service performance of the coating like a suitable barrier against hydrogen permeation, preventing the hydrogen damage of the steel substrates.
- Diffusivity measurements are based on steady state flux of hydrogen and the validity of the Sievert's law.
- Hydrogen permeability is commonly described based on the Fick's first law.
- Diffusion coefficient D is consistent with the Arrhenius equation.

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