

THE UTILIZATION OF PHOTOVOLTAIC SYSTEMS FOR ELECTROCHEMICAL PROCESSES

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Abstract

The paper deals with utilization possibilities of solar energy (photovoltaic systems) and with transformation of this energy to chemical energy and its utilization on the surface treatment of metals by electrochemical processes. Surface treatment takes part in the final surface quality of technical equipment. They influence its period of service, reliability in operation, readiness and requirements for maintenance. This technology could have high application in machinery industry in the future, for the possibility of cheap electrical energy generation. Next advantage of this electrical energy generation is the decrease of negative environmental damages.

Key words

photovoltaic, electrochemical processes, nickel coating

Introduction

Solar energy is the main condition of the live on the Earth. Solar radiation is possible to use directly for the generation of heat, cold and power. Indirectly, it is possible to use solar energy through hydropower, wind energy, energy of sea waves, heat energy of environs and energy of biomass [1,4]. Thanks to photoelectric effect in semiconductor, we can transform solar energy in the solar cells to power energy. Transformation of solar energy to power energy has widespread utilization. Disadvantage of solar energy production its dependence on day light, season and cloudiness in the area. Even though, it is potential energy, which is

impossible to ignore [1,5]. Photovoltaic effect, which permits to construct photovoltaic (PV) cell, was discovered by A.Becquerel in 1839 [2,4]. Subsistence of the PV transformation from solar radiation to power energy is so-called inert photovoltaic effect.

If solar radiation falls on the semiconductor material, then the concentration of charge carrier will rise compared to the condition without illuminance.

Incident photons transfer their energy, so electrons and holes will excite, what can be used for current conduction. It is necessary, that the electric field is made in semiconductor, which will isolate electrons and holes from each other. This kind of field is acquired by PN junction [5]. Equipment that can use this effect is called a photovoltaic (solar) cell. This equipment directly changes solar radiation to direct current (DC) [3,4,5]. The solar photovoltaic cell is a semiconductor diode. It is implemented like that, in the thin slice of silicium (Si) in the small depth under surface created PN junction, which is provided from the both sides by appropriate metal contacts. When solar radiation falls on the cell, electrons and free holes are generated. Electric field of PN junction separates them, and sends them to opposite side; electrons to the N layer, which becomes a negative pole of the photovoltaic cell and holes to P layer, which becomes a positive pole. Electric voltage is generated on the contacts and electric current starts to flow to an appliance [2,3,6].

Electrochemical processes

Electrochemical processes don't present the most significant place in production technologies, but perpetually inconvertible place. They are mainly applied in the sphere of surface modifications (electroplating, polishing, bating, degreasing, cauterization), in production of native metals (refining of copper, nickel, silver, gold.), and in production of gases (chlorine) or metals (aluminium, magnesium). Besides these technology processes, the electrochemistry finds applying for example in electrolytic work or sharpening of tools. All presented technology processes take place in environs of electrolyzers and electrolytic baths of different sizes and types [7,8].

Electroplating

By electroplating the coats are made in electrochemical reaction, and with the help of current the layer of coating metal is made. Coats can be made electrochemically, too they are copper, nickel, chrome, zinc, tin, cadmium, silver, gold and other coats. Electroplating is one of the most difficult surface adjustment technologies for pretreatment products. It is understandable, because the transmission of metal ion from solution on the surface of cathode and its incorporation to the crystal grid require perfect contact of phases. Selection of technology depends on the type of electroplating products and bath, electroplating technique, condition of surface and technique equipment of electroplating plant [9,11].

Nickel coating

Nickel coats have the widest application, because they verify requirement of anticorrosive protection with requirement of decorative appearance. Nickel anticorrosive protection is proportional to coat thickness. Nickel very good resists corrosion in all types of surrounding. Nickel coats are sometimes covered with thin chrome layer for decoration purposes. In special cases it is also possible to use as coat silver, gold, platinum or stannum [10].

Experiment

Technological procedure of nickel coating

In this experiment were used steel tin plates, with approximately 50 x 50 mm parameters and with weight about 11 g. Most of plates' surface was hit by a corrosion and grease. By electroplating, it is necessary to take care of pretreatment of product, because metal ion incorporating from solution to crystal grid requires perfect contact of phases.

Mechanical pretreatment

Abrasive paper was used on the removal of hard-impurities and asperities caused by drilling. A part of rust was possible to remove by simple motions in various directions.

Rinse

This operation was allotted in between each treatment and also as a finish treatment. In the beginning, the rinse was done by sprinkling with distilled water, but this method left marks after drying. Therefore, rinse by immersion to hot water was selected.

Chemical pretreatment

Following chemical pretreatments were performed after mechanical pretreatment:

- **degreasing** - it is removal of all kinds of impurities from surface, they are bound by either physical adsorption or adhesive forces. Composition of a degreasing bath was determined according to the level of surface contamination and also according to type of material,
- **bating** - it is the removal of corrosion products from metal surfaces by chemical or electrochemical manners. It was realized after surface degreasing,
- after bating, **decapping**, what is soft bating, can follow, but it is not necessary. In this experiment the process of decapping was skipped and after rinsing, galvanic coating followed.

Nickel coating

The base of electrolytic excretion of metals is a sufficient performance source of direct current. For galvanotechnique low voltage at intervals 2 - 12 V is used. Electric current is determined by the area, which we want electroplate. For nickel coating, two possibilities of types of surfaces exist - polished or opaque ones. Composition of bath is in Table 1.

COMPOSITION OF BATH FOR CREATING OPAQUE NICKEL COATING

Table 1

Compound	Weight of compound for one litre of bath [g]	Temperature [°C]	Time [min]	Current density [A .dm ⁻²]
Nickel Sulphate (NiSO ₄ .7H ₂ O)	240 - 450	55	25	3 - 5
Nickel Dichloride (NiCl ₂ .6H ₂ O)	20 - 90			
36% Boric Acid (H ₃ BO ₃)	20 - 50			

For polished surfaces thiocarbamide $\text{CH}_4\text{N}_2\text{S}$ with concentration 0.2 g. l^{-2} was added into the bath. During electroplating bath it was mixed by on magnetic stirrer.

Experimental equipment for nickel coating with PV panels

In the experiment, PV solar panel, which is installed in the solar laboratory at STU MtF in Trnava, was used as an electric power source. Basic parameters of PV solar system:

- optimal performance (peak) (+/-10 %): 50 W,
- nominal voltage: 12 V,
- optimal voltage (+/-10 %): 17.4 V,
- off-load voltage (+/-10 %): 21.4 V,
- optimal current (+/-10 %): 2.97 A,
- off-load current (+/-10 %): 3.27 A,

In this part, proceeding was according to the scheme, which is presented in Figure 1. Regulable source was directly substituted by PV panels (FVP), because the connection of PV panels was locally in the front of cabling to voltage changer. Figure 2 shows experimental electrolyser.

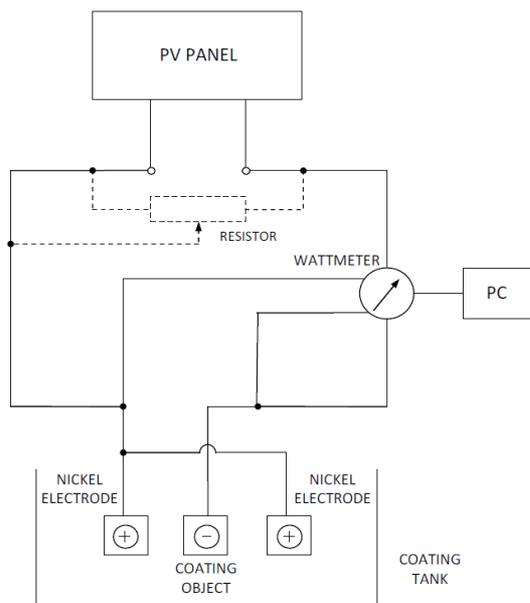


Fig. 1 Scheme of experimental set with energy obtained from PV panel

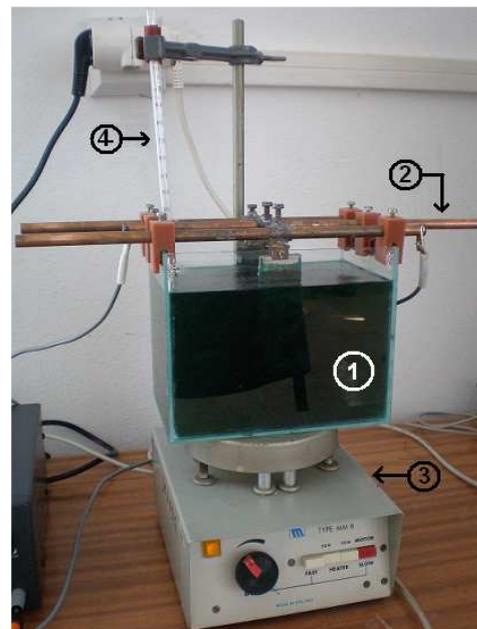


Fig. 2 Experimental electrolyser (1-glass tank, 2 – copper hangings 3 – magnetic stirrer with heating, 4 – thermometer)

For determination of **maximal coating area**, average value of solar radiation during the experiment was necessary to find out. The next needed value is the highest intensity of solar radiation during the whole operation of the solar laboratory. From these values according to Formula 1 is possible to acquire maximal coating area.

$$I_{\max} = \left(\frac{I_n}{N_n} \right) \cdot N_{\max} \quad (1)$$

where

I_{\max} - the highest value of produced current at maximal recorded solar radiation intensity [A],

I_n - the highest measured value of electrical current during experiment [A],

N_n - solar radiation intensity during experiment [$\text{W} \cdot \text{m}^{-2}$],

N_{\max} - the highest recorded solar radiation intensity in the laboratory [$\text{W} \cdot \text{m}^{-2}$].

This value can be then used in the final Formula 2 for determination of the biggest possible coating area;

$$S_{\max} = \frac{I_{\max}}{I_s} \quad (2)$$

where

S_{\max} - maximal coating area [dm^2],

I_s - current density (for nickel coating 3 - 5 $\text{A} \cdot \text{dm}^{-2}$) [A].

Excluding velocity of galvanic bath was determined by the Formula 3;

$$v = \frac{m}{t} \quad (3)$$

where

v - excluding velocity [$\text{g} \cdot \text{s}^{-1}$],

m - weight of excluded coating [g],

t - coating time [s].

Thickness of excluded coating can be determined in two ways, either calculation or measurement with micrometer. Formula 4 was used for calculation of coating thickness;

$$h = V \cdot \frac{10^3}{S} \quad (4)$$

where

h – Thickness of excluded coating [μm],

V – Volume of excluded coating [m^3],

S – Plate area [m^2].

Results and discussion

Study of nickel coating with utilization of PV panels

At all experiments we have worked with constant temperature 55 °C and constant time 150 seconds.

Weight of tin plate before nickel coating: $m_1 = 10.8817$ g.
 Average value of solar radiation during experiment : 748 W.m^{-2} .
 Maximum measured value of electrical current during experiment: 2.97 A.
 Weight of tin plate after nickel coating: $m_2 = 11.2378$ g.
 Weight of excluded coating: $\Delta m = 0.3561$ g.

Determination of maximum coating area

Maximum recorded value of solar radiation intensity in solar laboratory is 1033 W.m^{-2} . This experiment ran over 20. 5. 2010 at 13:30 - 13:50, and the value of solar radiation intensity was 748 W.m^{-2} . The values of produced electric current at this intensity were around 2.97 A. At the intensity of 1033 W.m^{-2} , according to Formula 1, it is possible to achieve around 4.1 A.

On the assumption that recommended current density is at intervals $3 - 5 \text{ A .dm}^{-2}$, then according to Formula 2, it is possible to coat matters with the area 1.4 dm^2 . However, for the ideal values of current density (4 A .dm^{-2}) are around 1 dm^2 .

Excluding velocity (according to Formula 3)

Weight of excluded coating: $m = 0.3561$ g,

Coating time: $t = 1500$ s

Excluding velocity: $v = 2.3740 \cdot 10^{-4} \text{ g.s}^{-1}$

Average thickness of coating (according to Formula 4)

Volume of excluded coating: $V_{\text{Ni}} = 0.4001 \cdot 10^{-7} \text{ m}^3$

Area of tin plate: $S = 0.005 \text{ m}^2$

Average thickness of coating: $h_{\text{Ni}} = 8.002 \text{ }\mu\text{m}$

Visual evaluation

Figure 3 shows correct excluded opaque coat: light rough, homogenous and coat total adhesives to the tin surface. Figure 4 illustrates correct excluded polished coat: light rough, homogenous and coat total adhesives to the tin surface.



Fig. 3 Appearance of correct nickel-coated tin with opaque coat at electrical energy generation from PV panels



Fig. 4 Appearance of correct nickel-coated tin with polished coat electrical energy generation from PV panels

Conclusion

The main task of the paper was to verify the photovoltaic system of solar laboratory and find the utilization possibilities of this system for electrochemical processes.

The whole system is now usable for electroplating, but for the low capacity we can use only the system for subjects with small areas, around 1 dm², 1.4 dm² in ideal conditions. Excluding velocity of bath was 2.3740 · 10⁻⁴ g.s⁻¹ and average thickness of coating was 8.002 μm.

This paper was elaborated within project **VEGA no. 1/0798/08 „Development and utilization of small hydroenergetic source Setur in the combination with solar equipment for mechanical technologies“.**

References:

- [1] BERANOVSKÝ, J., TRUXA, J., et al. *Alternative energy for your house*. Brno : ERA, 2004. ISBN: 80-86517-59-4
- [2] MURTINGER, K., TRUXA, J. *Solar energy for your house*. Brno : ERA, 2006. ISBN 80-7366-076-8
- [3] MURTINGER, K. et al. *Photovoltaic – energy from sun*. Brno : ERA, 2007, ISBN 978-80-7366-100-7
- [4] LUQUE, A., HEGEDUS, S. *Handbook of Photovoltaic Science and Engineering*. John Wiley & Sons Ltd, 2003. ISBN 0-471-49196-9
- [5] MESSENGER, R. VENTRE, J. *Photovoltaic Systems Engineering*. New York : CRC Press LLC, 2005. ISBN 0-8493-1793-2
- [6] MARKVART, T., CASTANER, L. *Solar Cells: Materials, Manufacture and Operation*. Amsterdam : Elsevier, 2005. ISBN:1-85617-457-3
- [7] KRAUS, V. *Surface and its treatment*. Plzeň : The West-Czech Univerzity, 2000.
- [8] KUDLÁČEK, JAN. *Problem of surface pretreatment*. In *Surface treatment*, volume 1, 2007. Internet source : <<http://www.povrchovauprava.cz/casopis>> (10.4.2008)
- [9] European Committee for Surface Treatment, *Surface Treatment of metals and plastic materials using electrolytic or chemical process*, May 2002. Internet source: <<http://www.sits.fr/htm/Anglais/FinalBREF%20TS%20May2002.pdf>> (12.4.2008)
- [10] KANANI, N. *Electroplating - Basic Principles, Processes and Practice*. Amsterdam : Elsevier, 2005. ISBN 1856174514
- [11] SCHLESINGER, M., PAUNOVIC, M. *Modern Electroplating*. New York : John Wiley & Sons, Inc., 2000. ISBN 0-471-16824-6