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BRIGHT COPPER PLATING USING PHOTOVOLTAIC AS AN ENERGY SOURCE

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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 as well as its utilization in the surface treatment of metals by electrochemical processes. Surface treatments significantly contribute to the resulting quality of technical equipment. Surface treatments affect lifetime, serviceability, usability, availability and maintenance of equipment. This technology can be widely applied in machine industry in the future due to cheap electrical energy generation. Next advantage of this electrical energy generation is the decrease of negative environmental impact. The whole system is now usable for bright copper plating, but owing to the low capacity, we can use it only for the objects of small areas, around 1.10 dm^2, 4.39 dm^2 in ideal conditions.

Key words

photovoltaic, electroplating, bright copper plating

Introduction

Solar energy is the main prerequisite of the life on the Earth. Solar radiation is a direct source for generating 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 semiconductors, we can transform the solar energy in solar cells to power energy. Transformation of solar energy to power energy has wide utilization. Disadvantage of solar energy generation is its dependence on daylight, season and cloudiness in the area. Even though, it is a potential energy, which should not be ignored (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.

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

Incident photons transfer their energy making electrons and holes 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. PN junction is formed in the thin slices of silicon in a small depth below the surface whith metal contacts both sides. 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 sides; 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 flowing to an appliance (2, 3, 6). Generally, solar photovoltaic systems fall into two main groups:

- systems are connected to the electricity grid - a "grid connected system" or just "on grid",
- systems without connection to the electricity grid - "off grid".

In some cases, a combination of both is used forming so-called hybrid or insular system that can supply electricity to the grid or operate completely independently (3). They are rarely found in the household because of the high investment costs. Regarding the changes in the economic sphere as well as dumping prices, these devices are expected to be widely used in the field of civil engineering (7).

Electroplating - Copper plating

Electroplating uses electric current and electrochemical reaction for making metal coatings. Coatings may be formed by copper, nickel, chromium, zinc, tin, cadmium, silver, gold and others. Electroplating is one of the most difficult surface adjustment technologies for pretreatment products. It is clear, 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 technical equipment of electroplating plant (8, 9, 11). Technology of electroplating has been known for a long time, and it has been used for preparation of coating in models of complex form (galvanoplatics), and for thin coating on subjects for the purpose of protecting metals mostly from corrosion (galvanization). Electrochemical processes are of major importance for this branch.

Copper coats are most often used as an intermediate layer for protective or decorative electroplating in nickeling and silvering, either as a protective layer in cementation in galvanoplastics, or as a decorative coat. In last case, excluded coating must be protected from the corrosion effects of the outside atmosphere by a suitable coat. The most often used copper baths are cyanide solution and acid baths with brightener. Properties of excluded copper coatings depend on their structure, the type of bath and its composition. (11, 12).

Experiment

Technological procedure of bright copper plating

This experiment used thin sheets with approximately 50 x 50 mm with the weight of about 11g. Most of the plates' surface was hit by corrosion and grease. Pretreatment before electroplating is very important because the inclusion of metal ion from solution to the crystal lattice requires perfect contact phases.

Mechanical pretreatment - Abrasive paper was used for the removal of hard impurities and asperities caused by drilling. A part of the rust was removed by simple motions in various directions. **Rinse -** This operation was included among 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 – The following chemical pretreatments were performed after mechanical pretreatment:

- **degreasing -** removal of all kinds of impurities from surface. Composition of a degreasing bath was determined according to the level of surface contamination and also according to the type of material,
- **bating -** removal of corrosion products from metal surfaces by chemical or electrochemical ways. It was carried out after surface degreasing,

Copper plating - 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 to be electroplated. For copper plating, there are two types of surfaces - polished or opaque ones. Composition of polished bath is shown in Table 1. Electroplating bath was stirred with a magnetic stirrer.

COMPOSITION OF BATH FOR MAKING OPAQUE COPPER PLATING Table 1

Compound	Weight of compound for one litre of bath [g]	Temperature [°C]	Time [min]	Current density [A .dm^{-2}]
$CuSO_4.5H_2O$	160 - 230	20	20	1 - 8
97% H_2SO_4	60 - 78			
CH_4N_2S	0.2			

Experimental equipment for copper plating using PV panels

In the experiment, PV solar panels which were installed in the solar laboratory at SUT FMST Trnava were used as an electric power source. Basic parameters of PV solar systems:

- panel STR 36-50, optimal performance (peak) (+/−10 %): 50 W,
- panel AIT SG65, optimal performance (peak) (+/−10 %): 65 W,
- system SOLARTEC SG, optimal performance (peak) (+/−10 %): 645 W.

Figure 1 presents the scheme of experimental procedure, while Figure 2 shows experimental electrolyser.

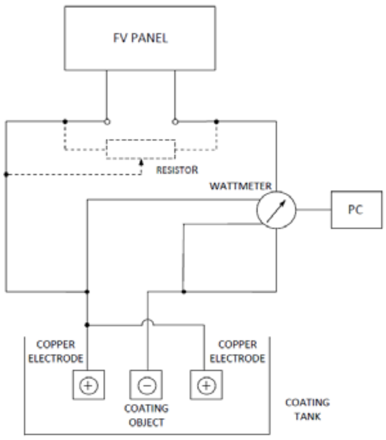

Fig. 1 *Scheme of experimental set with energy obtained from PV panel*

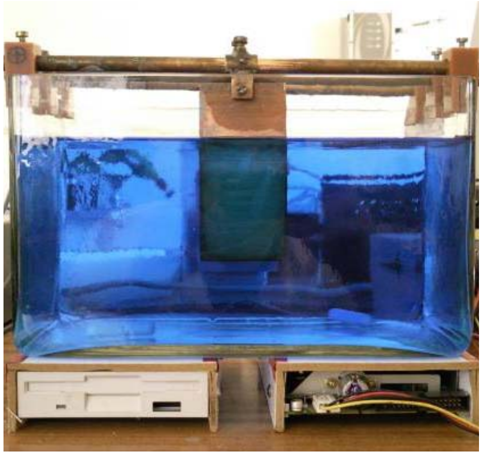

Fig. 2 *Experimental electrolyser*

To determine maximal coating area, it was necessary to find the average value of solar radiation during the experiment. Another needed value was the highest intensity of solar radiation during the whole operation of the solar laboratory. Supplying these values into Formula 1, it is possible to acquire maximal coating area.

$$\mathrm{I}_{\max} = \left(\frac{I_n}{N_n}\right) \cdot N_{\max}, \qquad [1]$$

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 [W. m^{-2}],

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

This value can be then used in the final Formula 2 to determine the biggest possible coating area;

$$S_{\max} = \frac{I_{\max}}{I_S}, \qquad [2]$$

where

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

I_S - current density (for copper plating 1 - 5 A.dm^{-2}) [A].

Excluding velocity of galvanic bath was determined by Formula 3;

$$v = \frac{m}{t}, \qquad [3]$$

where

v - excluding velocity [g.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;

$$h = V \cdot \frac{10^3}{S}, \qquad [4]$$

where

h – Thickness of excluded coating [µm],

V – Volume of excluded coating [m^3],

S – Plate area [m^2].

Results and discussion

RESULTS OF BRIGHT COPPER PLATING Table 2

PV system	Current density	Solar radiation	Weight before plating	Weight after plating	Weight of excluded coating	Thickness of coating	Excluding velocity
	J [A.dm^{-2}]	N_n [W.m^{-2}]	m_1 [g]	m_2 [g]	Δm [g]	h [µm]	v [g.s^{-1}]
STR 36-50	4	697	10.5923	11.4582	0.8659	19.3931	0.0007
AIT SG65	4	747	10.6782	11.5915	0.9133	20.4546	0.0008
SG	4	721	10.6357	11.5568	0.9211	20.6293	0.0008

Table 2 shows results of bright copper plating. The difference of weight coatings using all the solar panel is minimal, ranged from a tenth of a gram. Also, excluded coating thickness and excluding velocity were approximately the same. It follows that the bath had a good ability of exclusion.

Determination of maximum coating area

RESULTS OF DETERMINATING THE MAXIMUM COATING AREA Table 3

PV system	Current density	Highest value of current	Solar radiation	Maximal coating area
	J [A.dm^{-2}]	I_n [A]	N_n [W.m^{-2}]	S_{max} [dm^2]
STR 36-50	4	2.83	726	1.10
AIT SG 65	4	3.43	773	1.25

For example (PV system 36-50): maximum recorded value of solar radiation intensity in solar laboratory is $N_{max} = 1125$ W.m^{-2}. This experiment ran over 5. 5. 2011 at 12:30 -14:50, and the value of solar radiation intensity was 726 W.m^{-2} (Table 3). The values of produced electric current at this intensity were around 2.83 A. At the intensity of 1125 W.m^{-2}, according to Formula 1, it is possible to achieve around 4.39 A.

Assuming the recommended current density in the range 1 - 8 A.dm^{-2}, we can coat objects with area up to **4.39 dm^2** according to the formula No. 2. **1.10 dm^2** in compliance with the current density 4 A.dm^{-2}.

Visual evaluation

Figure 3 shows the correct excluded bright coat: light rough, homogenous and coat total adhesives to the tin surface. Figure 4 illustrates microscopic image of the correct bright copper coated tin in ten times magnification. Coat perfectly adheres to the metal surface without signs of delamination or other defects.

Fig. 3 *Appearance of correct bright copper coated tin with bright coat using PV panels*

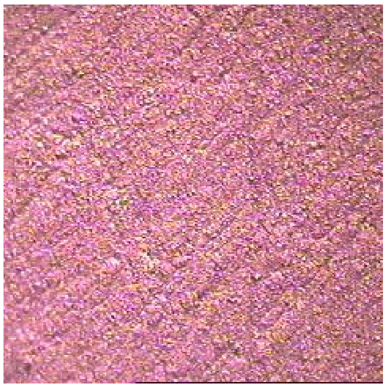

Fig. 4 *Microscopic image of correct bright copper coated tin in ten times magnification*

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 – copper plating.

The whole system is now used for bright copper plating, however, due to the low capacity we can use the system only for subjects with small areas, around 1.10 dm^2, 4.39 dm^2 in ideal conditions. The result of visual assessment of the coated sheets is that on sunny days, and with good intensity of solar radiation, photovoltaic process can be easily competed with the usual sources of electricity. Used photovoltaic panels have sufficient capacity for the coating technology.

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