# A SYSTEM TO MEASURE THE CURRENT EFFICIENCY AND ENERGY SPECIFIC CONSUMPTION FOR BDD ELECTRODE

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**REZUMAT. In această lucrare, autorii prezintă un sistem ce utilizează instrumentaţia virtuală în scopul evaluării criteriilor de performanţă precum randamentul de curent şi consumul specific de energie pentru imbunătăţirea materialului de diamant dopat in cazul utilizării ca electrod de lucru sau ca semiconductor.**

**Cuvinte cheie:** electrod BDD, instrumentație virtuală, randament de curent, consum specific de energie.

**ABSTRACT. In this paper the authors presents a proposed system that make use of virtual instrumentation for evaluation of performance criteria's like current efficiency and energy specific consumption to improve diamond doped material in case of working electrode and semiconductor behaviour.**

**Keywords: BDD electrode, virtual instrumentation, current efficiency, energy specific consumption**

## 1. INTRODUCTION

Boron Doped Diamond (BDD) electrodes are an innovation with a high market potential that have attracted considerable attention for electro analytical detection of variety analytes including trace metals. BDD electrodes are superior different applications due to their excellent properties such as chemical inertness, corrosion resistance, durability, good electrical conductivity, low background current and large potential window between oxygen and hydrogen evolution. The unique properties of BDD electrodes make them the proper choice for on-line monitoring units. Also diamond electrodes exhibit semiconducting or metallic conductivity depending on the boron doping level.

With these properties, diamond is a suitable material for many industrial applications. Can be identified three classes of electrochemical applications: synthesis of chemical compounds, electro-analysis, breakdown of pollutants.

There are numerous studies and applications of this synthetic material (diamond doped with boron) deposited on different substrates: Si support (most studies, even if problems arise fragility and low conductivity of Si substrate), support of Nb (widespread use of this substrate is unlikely due to its high cost), Ti support (it is less expensive but is not yet a method for submitting industrial stable layer of diamond, because the cracks that lead to separation film duration of electrolysis large diamond). BDD electrode is an attractive anode material for degradation of refractory or priority pollutants such as ammonia, cyanides, phenol, chlorophenols, aniline, various dyes, alcohols and many other compounds. Unlike PbO2, SnO2 and TiO2, BDD film deposited on Si Ta, Nb and W by CVD (chemical vapour deposition) have been shown to have excellent electrochemical stability [1].

Another important aspect is the production of strong oxidants such as peroxo-disulfat [2], species that can participate in oxidation of organic substrates with high efficiency. In particular, for high concentrations of organic pollutants and low current density, chemical oxygen demand (COD) decreases linearly and instantaneous current efficiency (ICE) remains about 100%, indicating a kinetically controlled process. While for low concentrations of organic pollutants or high current densities, COD decreases exponentially and ICE begins to decrease because of limited mass transport and side effects of oxygen evolution [3]. For a better understanding of the results, Panizza developed a kinetic model that allows estimation, on the one hand, the trend COD and current efficiency for degradation of organic compounds at BDD electrode and on the other hand, energy consumption during process [4].

In present study there are analyzed the behaviour of BDD anode in case of mineralization of a dye solution (CV Cristal Violet) by Advanced Oxidation Processes (AOPs) in order to evaluate the performance criteria: current efficiency and energy specific consumption for improvement of BDD in case of working electrode and semiconductor behaviour.

After Glaze, Advanced Oxidation Processes (AOPs) are: "water treatment processes involving hydroxyl radical generation, temperature and ambient pressure, in an amount sufficient to effect purification of water" [5]. In other words, AOP are clean methods involving degradation processes (chemical, photochemical, photo-catalytic, or electro-chemical) which are based on highly oxidizing species production and therefore very unstable, such as hydroxyl radicals (HO.), with the highest redox potential (Eo2.80V) after fluorine (Eo 3.03V).

AOP have characteristics that define them as promising technologies for water treatment [6]: are very effective methods for destruction of organic compounds with a low level; are able to achieve total conversion to CO2, H2O and inorganic ions (mineralization) showing a non-selective reactivity that minimizes accumulation of toxic intermediates of degradation; presents a high efficiency in destroying contaminants.

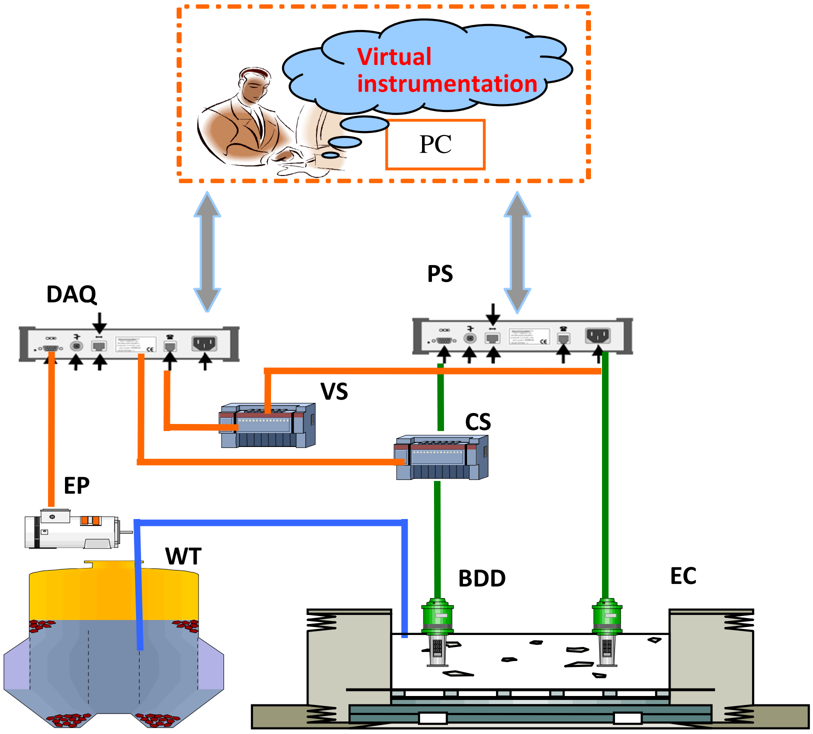


**Fig. 1.** System for study of current efficiency and energy specific consumption at BDD electrode.

## 2. SYSTEM ACHITECTURE

**General considerations:**

The electro-chemical determinations and experiments are performed with an undivided electrolytic cell of 100 mL with boron-doped diamond (BDD) (with 3cm2area) and C-PTFE O2-diffusion cathode in aqueous media at pH 3.0, under galvanostatic conditions. The experimental system is described elsewhere [7][8].

Today's technology does not allow large-scale marketing BDD electrodes doped with different metal oxides, polymers, etc. Therefore, creating an automatic system for evaluation of BDD performance criteria's like current efficiency defined in equation (4) and energy specific consumption defined in equation (5), with metal or semiconductor behaviour, using specific measurement methods, can provide new stable and reproducible production technologies at industrial scale.

**Analysis model:**

Mineralization current efficiency (MCE) is defined as a relationship between the amount of mineral compound and which could theoretically mineralized [9]. Starting from the decreasing values of TOC's MCE can be calculated at a given time for the mineralization (conversion to $CO_2$, $H_2O$ and inorganic ions) of the dye studied (Eq. 1):

$$MCE = \left[\frac{\Delta(TOC)_{exp}}{\Delta(TOC)_{teor}}\right] \times 100 \quad (1)$$

where $\Delta(TOC)_{\exp}$ corresponds of values of TOC experimentally obtained at a given time; $\Delta(TOC)_{teor}$ is decreasing TOC's theoretical the time given, considering that the applied electrical charge (current x time) is consumed only in reaction of to mineralization of dye studied.

Mineralization current efficiency ($\eta_{MIN}$, %) is defined as the ratio of experimental TOC variation and variation of theoretical TOC (Faraday's law) (Eq. 2):

$$\eta_{MIN} = \frac{(\Delta_{TOC})_{\exp}}{(\Delta_{TOC})_{teor}} \times 100 \qquad (2)$$

where:

$$(\Delta_{TOC})_{teor} = \frac{I \cdot M_C \cdot n_C \cdot \tau \cdot 10^3}{z \cdot F \cdot V_L} \qquad (3)$$

replacing Eq. (2) in Eq. (3) is obtained (Eq. 4):

$$\eta_{MIN} = \frac{(\Delta_{TOC})_{\exp} \cdot z \cdot F \cdot V_L}{I \cdot M_C \cdot n_C \cdot \tau \cdot 10^3} \times 100 \qquad (4)$$

where: $I$ is current intensity, (A); $M_C$ is atomic mass of carbon (= 12 g/mol); $n_C$ is number of atoms of carbon from CV molecule (= 25); $z$ is number of electrons transferred in mineralization; $F$ is Farday number (= 96487 C/mol); $\tau$, time of mineralization, (h); $(\Delta_{TOC})_{\exp}$, variation of total organic carbon (mg/ L) from solution, between initial moment and time $\tau$.

Specific electricity consumption ($\varepsilon$), in kWh/ g TOC is defined by Eq. (5):

$$\varepsilon = \frac{U_{cel} \cdot I \cdot \tau}{(\Delta_{TOC})_{\exp} \cdot V_L} \qquad (5)$$

where $U_{cel}$ is the voltage of electrolysis cell (V).

**System description**

The LabVIEW environment was incorporated in centre concept towards creating a unique and powerful distributed application, combining together different measurement nodes and multiple users into a unique measurement controlling system, in order to integrate and revolutionize the fundamental architecture of actual PC-based measurement solutions.

All PC interfaced apparatus used for studying the influence of major operating factors investigated, in order to find the optimal conditions improve the quality of measurements.

The present system has the capability to perform tasks that diminish the work quantity of a specialized person and is capable to communicate with other computers.

The system depicted in Figure 1, has three closed circuits: water circuit (blue), sensors data circuit (orange), power circuit (green), digital information (gray). The modules components are: BDD electrodes, EC -electrochemical cell, DAQ - NI USB-6211 data acquisition board, WT-water tank, EP – electrical pump, VS – voltage sensor, CS – current sensor, PS – power supply and a computer with LabVIEW software.

All this hardware perform as an automatic system controlled by LabVIEW software and allowing as to perform advanced study of current efficiency and energy specific consumption at BDD electrode. The data acquisition board communicate via USB port using a simple interface. We use 2 analog inputs from the data acquisition board for measuring the current and voltage throughout BDD electrodes and treated solution. The PWM output is used to control the speed of the electrical pump and thus the circulation speed of the treatment solution, in dynamic regime. The power supply can be controlled by PC and generate different current values.

## 3. CONCLUSIONS

Many papers have demonstrates that the using of this synthetic material deposited on several supports, provides total mineralization of pollutants (total conversion to CO2, inorganic ions and water). The nature of support substrate is an important factor in diamond production because it determines directly or indirectly the feasibility of whole process.

The proposed system is quite simple and is flexible, include data acquisition systems that combined with LabVIEW software, become a very useful measurement instrument.

This system has at direct impact improvement of doped diamond materials manufacturing as electrode suitable for sensors and biosensors. Using LabVIEW software, research results regarding current efficiency and energy specific consumption will lead to improved product quality and lower cost prices.

The system presented can be well integrated in a distributed measurement system for the electrochemical field and especially in the water treatment field. Using LabVIEW software we assure the flexibility and the portability of the system.

*Table 1*

**Current efficiency and energy consumption mineralization, corresponding to mineralization of CV on BDD anode and C-PTFE cathode with diffusion of O2 by AO, EF and PEF. (experimental electrochemical conditions: I = 300 mA , T = 308 K, pH = 3,0, buffer solution Na2SO4 50mM).**

| Time, (τ) min | AO | | | EF | | | PEF | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\eta_{MIN, \%}$ | ε, KWh/g TOC | TOC, mgC/L | $\eta_{MIN, \%}$ | ε, KWh/g TOC | TOC, mgC/L | $\eta_{MIN, \%}$ | ε, KWh/g TOC | TOC, mgC/L |
| 60 | 12.54 | 1.45 | 70.61 | 12.48 | 0.65 | 35.58 | 30.11 | 0.84 | 29.45 |
| 120 | 10.22 | 1.68 | 52.06 | 8.37 | 1.05 | 28.85 | 16.45 | 1.28 | 22.89 |
| 360 | 6.51 | 2.49 | 8.43 | 3.47 | 2.62 | 6.48 | 6.72 | 3.11 | 1.50 |

## ACKNOWLEDGMENT

This paper was supported by the project PERFORM-ERA "Postdoctoral Performance for Integration in the European Research Area" (ID-57649), financed by the European Social Fund and the Romanian Government" and by the project "Development and support of multidisciplinary postdoctoral programmes in major technical areas of national strategy of Research - Development - Innovation" 4D-POSTDOC, contract no. POSDRU/89/1.5/S/52603, project co-funded by the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013.

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