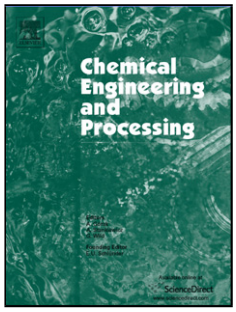


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# Intensification of a Flat-Plate Photocatalytic Reactor Performances by Innovative Visible Light Modulation Techniques: a Proof of Concept

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- Visible Light Modulation Techniques can improve Photocatalytic Reactor Performance
- A flat-plate photocatalytic reactor has been adopted for the prototype development
- Visible-light-active N–TiO2 have been adopted as photocatalyst
- Precise LEDs dimming control and efficient power stage control have been performed
- Dimming techniques for photoreactor irradiation have been experimentally verified

***Abstract* - This paper investigates the effect of controlled periodic illumination by visible LEDs on the performances of a flat-plate photocatalytic reactor for wastewater treatment. Different LED dimming techniques are investigated and compared, including the classical Pulse Width Modulation (PWM) technique and a novel proposed Variable-Peak PWM technique. A modulation of dimming duty-cycle is adopted as well, which allows to control the light irradiation in a new way with respect to previously used methods. Experimental results highlight the improvement in the photocatalytic degradation process obtained by using the proposed modulation techniques.**

***Keywords* - Photocatalysis, Flate-Plate Photocatalytic Reactor, LED Dimming, Pulse Width Modulation**

## I. INTRODUCTION

Heterogeneous photocatalysis is one of the promising ways of wastewater treatment [1]. It is based on the use of semiconductors as photocatalysts, which can be excited by the absorption of photons emitted from solar or artificial light sources [2]. *ZnO* and $TiO_2$ are the semiconductors most studied as photocatalysts in the degradation of pollutants, both from wastewaters and gaseous streams [3]. However, as their band-gap value is in the range 3.0-3.2eV, they can be activated by less than 5% of the complete solar spectrum. Therefore, they must be modified to enhance the absorption of visible light as much as possible [4]. Recently, a visible-light-active *N*-doped $TiO_2$ ($N{-}TiO_2$) has been proposed in literature. $N{-}TiO_2$ has a band-gap value of 2.5eV, resulting very effective in the removal of organic dyes, such as Methylene Blue (MB) and Methyl Orange (MO) [5].

Low Quantum Efficiency (QE) of photocatalytic processes represents a critical issue in the use of photocatalysis for wastewater treatment. In particular, QE needs to be improved in order to make the photocatalytic process economically competitive with traditional method used in the treatment of polluted water streams. Controlled Periodic Illumination (CPI) has been recently presented as a promising approach to increase the QE in photocatalytic processes [6]. In this regard, Light Emitting Diodes (LEDs) represent the best light sources, since they can be electronically controlled by using dimming techniques, allowing variable turn-on and turn-off times on a microsecond time-scale. High efficiency, extensive life (approximately 50,000 hours), excellent vibration resilience and capability of providing directional lighting represent some of the major advantages of LEDs [7]. These features, including the ability to almost fully dim, allow LEDs to be perceived as the future in lighting technology, especially in UV-LED based technologies developed for water treatment and disinfection [8], [9]. In [10] it was reported that, generally, CPI of a photoreactor could promote the utilization of incident photons more efficiently than continuous illumination. The effect of UV-LEDs-based CPI on the QE of acetone photocatalytic removal has been discussed in [11], where rectangular light pulses have been adopted, demonstrating that the QE increases with the increase of light pulses frequency and the decrease of duty-cycle. In particular, experimental results suggest that the QE under the same average light intensity in continuous mode is always higher than in CPI mode. The effects of CPI realized by means of an UV-LEDs system for $TiO_2$-based photocatalytic processes have also been investigated in [12], [13]. Similarly, experimental verifications confirm that quantum yields under CPI do not exceed those attained by continuous operation, at equivalent average photon absorption rates. Lastly, the use of