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Improvement of diagnostic techniques and electrical circuit in azo dye degradation by high voltage electrical discharge

Yongjun Shen, Lecheng Lei *, Xingwang Zhang, Minghua Zhou, Yi Zhang

Institute of Environmental Pollution Control Technologies, Zhejiang University, Hangzhou 310028, PR China

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Abstract

Fast electrical diagnostics and improvement of electrical circuits for methyl orange (MO) degradation by high voltage pulsed electrical discharge were investigated. To eliminate electromagnetic radiation, several effective methods were employed. RG 218 coaxial cable was substituted for the common transmission lines to transmit high voltage pulses, and multi-lines in parallel were earthed to avoid electromagnetic interference and, additionally, to reduce the stray inductance of the electrical circuit and increase the pulse rise rate to reduce the energy losses in the transmission system. The problem of the differences in the bandwidths of voltage and current probes causing an error in the calculation of energy dissipation was avoided by reducing the bandwidths of voltage and current measurements to the same value. The real discharge current was obtained by subtracting the capacitive current from the total current. The energy per pulse obtained in the reactor before and after improvement of the diagnostics and electrical circuit were 15.5 mJ and 26.8 mJ, respectively, and the energy efficiencies of MO degradation were 1.34×10^{-9} mol/J and 1.95×10^{-9} mol/J, respectively.

Keywords: High voltage pulsed electrical discharge; MO degradation; Diagnostic techniques; Electromagnetic radiation; Stray inductance; Energy efficiency

1. Introduction

Organic synthetic dyes have been widely used as colorants in different industries such as textile, paper, color photography, pharmaceutical, food, cosmetic, etc. [1]. Wastewaters containing organic synthetic dyes present a very serious environmental problem because of their aesthetic nature and toxicity. Almost 70% of all reactive dyes are of the azo type.

Classical waste removal processes such as biodegradation and flocculation with iron salts methods are currently used, but they become inadequate nowadays with respect to the more drastic imposed environmental regulations [2]. Biodegradation of dyes is not efficient enough due to the presence of aromatic nuclei in the molecular structures. Polymerized aluminum salts have also been proposed for treatment of the industrial colored effluents from textile plants, but difficulties arise during liquid–solid separation. Bentonite has also been used to eliminate textile dyes, but the process is limited to acid solutions.

Recently, a pulsed high voltage process for treatment of hazardous chemical wastes in water has been developed [3–8]. The collisions of highly energetic electrons with molecules yield active ·OH radicals. Hydroxyl radicals, aggressive and non-selective species, directly attack organic compounds, leading to oxidation of these compounds. When a spark discharge is produced by pulsed high voltage, UV radiation, active species (radicals) and shock waves occur simultaneously [9]. These processes have a synergistic effect in the degradation of organic compounds and also in sterilization.

A high voltage pulsed electrical discharge is considered to be a promising alternative for treatment of pollutants, however, the independent pulse parameters, i.e., polarity, peak voltage, rise time, pulse duration and repetition rate,

* Corresponding author. Tel.: +86 571 88273090; fax: +86 571 88273693.
E-mail addresses: zjuenv@zju.edu.cn, lclei@zju.edu.cn (L. Lei).

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should be optimized. Accordingly, it is very necessary to perform a consistent set of measurements under conditions with adequate parameter variation. Diagnostics are applied with the intention to bridge the gap between theory and practice. The exact energy utilization efficiency cannot be obtained without exact discharge waveforms. Moreover, energy consumption is a very important factor in waste removal, and it must be reduced to the lowest possible level. As far as we know, there are few literatures about specific diagnostic techniques and improvement of electrical circuits for pulsed electrical discharges.

In this paper, we investigated fast electrical diagnostics and improvements of the electrical circuit for MO degradation by high voltage pulsed electrical discharge. Several effective methods were used to eliminate electromagnetic radiation, i.e. a hermetically closed metal cage surrounding the pulse forming circuit, a stainless cage surrounding the digital oscilloscope and metal tubes surrounding the cables. RG 218 coaxial cable was used to transmit the high voltage pulse and multi-lines in parallel were used to earth the circuit, which avoided electromagnetic interference and distortion of the waveforms and reduced the stray inductance of the electrical circuit. Thus, the pulse rise rate was increased, and the energy lost in the transmission system was reduced. The bandwidths of the voltage and current measurements were reduced to the same value to avoid errors in calculation of the energy dissipation caused by differences in the bandwidths of the voltage and current probes. The degradation processes achieved by the oxidizing species generated in the plasma were followed by UV–Vis spectroscopy. The energy efficiencies of MO degradation before and after improvement of the diagnostics and electrical circuit were discussed.

A new type of pulsed high voltage source was used in the experiments. In contrast to the traditional spark gap switch source used in our previous work [8,10–12], the main advantages of the new one include (1) increased safety, (2) avoiding spark noise and keeping the pulse frequency stable, (3) enabling easy adjustment of the Blumlein pulse forming net (BPFN) to match the pulsed high voltage source with the reactor.

2. Experimental

2.1. Experimental equipments and procedures

The sketched circuit of the pulsed high voltage source with thyratron switch is shown in Fig. 1a. Its principle is that the storage capacitor 3 is charged from a positive direct current (DC) high voltage source 2 firstly; the charge stored on capacitor 3 flows through an inductance 4 and a diode 5 to charge the BPFN 8 secondly; the high pulse voltage is

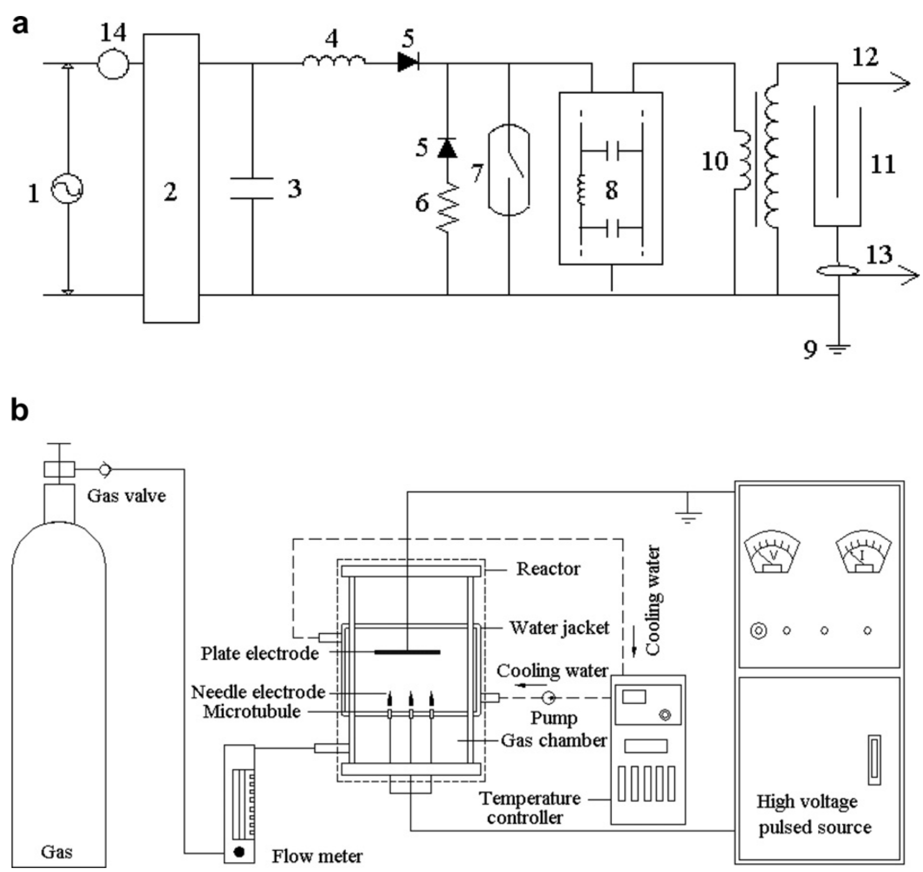

Fig. 1. (a) The topology circuit of pulsed high voltage source. (1) AC input (0–380 V); (2) DC high voltage source; (3) capacitor; (4) inductance; (5) diode; (6) resistance; (7) thyratron; (8) Blumlein pulse forming network; (9) earth point; (10) pulse transformer; (11) pulsed electrical discharge reactor; (12) voltage sampling; (13) current sampling; and (14) AC wattmeter. (b) The diagrammatic sketch of experimental apparatus.