Thin Solid Films 518 (2009) 924–928

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

Decomposition mechanism of organic compounds by DC water plasmas at atmospheric pressure

Hiroshi Nishioka, Hironori Saito, Takayuki Watanabe *

Dept. Environmental Chemistry and Engineering, Tokyo Institute of Technology, Yokohama, 226-8502, Japan

ARTICLE INFO

Available online 6 August 2009

Keywords:
Water plasma
Thermal plasma
Hydrogen production
Liquid waste treatment
Decomposition mechanism

ABSTRACT

The purpose of this paper is to investigate the decomposition mechanism of organic compounds by water plasmas. The plasma torch can generate 100%-steam by DC discharge without a commercially available steam generator. Methanol or ethanol used as a model substance of water-soluble organic compounds was mixed with water for plasma supporting gas. The main gases after the decomposition were H_2, CO, and CO_2. The 50 wt.% of carbon was transformed into solid carbon in 5 mol%-ethanol decomposition, while the solid-carbon formation from 5 mol%-methanol was negligible. Larger amount of solid-carbon formation from ethanol decomposition indicates the different mechanism between methanol and ethanol decomposition.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Wastes of 450 million tons a year are discharged by economic activities of mass production and mass disposal in Japan. Thermal plasmas provide the advanced solution for environmental problem. Thermal plasmas have received many attentions due to its high chemical reactivity, easy and rapid generation of high temperature, high enthalpy to enhance the reaction kinetic, oxidation and reduction atmosphere in accordance with required chemical reaction, and rapid quenching capability (10^5–10^6K/s) to produce chemical non-equilibrium compositions. Therefore, thermal plasmas have been widely applied to many fields because of these advantages, such as waste treatment, synthesis of nanoparticles, chemical vapor deposition and plasma spraying.

Waste decomposition using thermal plasmas have been reported, for example, halogenated hydrocarbon [1,2], hydrocarbon [3,4], polymer [5–7], organic waste [8,9], used tires [10], biomass [11–13]. When water plasmas are applied to waste treatments, the use of additional steam generator is unsuitable, because the steam generator requires complicated system including the heating-up of the steam feeding line for preventing from condensation.

The developed torch provides the generation of 100%-water plasma without a commercially available steam generator. The features of the torch results from the simple steam generation; liquid water from the reservoir is heated up and evaporates at the anode region to form the plasma supporting gas. Simultaneously, the anode is cooled by the water evaporation, therefore the electrodes require no additional water-cooling. The distinctive steam generation method provides the portable light-weight plasma generation system that does not require the gas supply unit, thus the high energy-efficiency results from the non-necessity of the additional water-cooling. Furthermore, hydrogen and oxygen in the produced gas suppress the recombination of by-products. These features of the proposed plasma generation method, which are not readily achievable by other methods, allow for simple and effective water plasma generation system.

The objective of this paper is to investigate the decomposition mechanism of organic compounds by DC water plasma at atmospheric pressure. Methanol and ethanol solution were used as the model substances of water-soluble organic wastes. Furthermore, wastes are

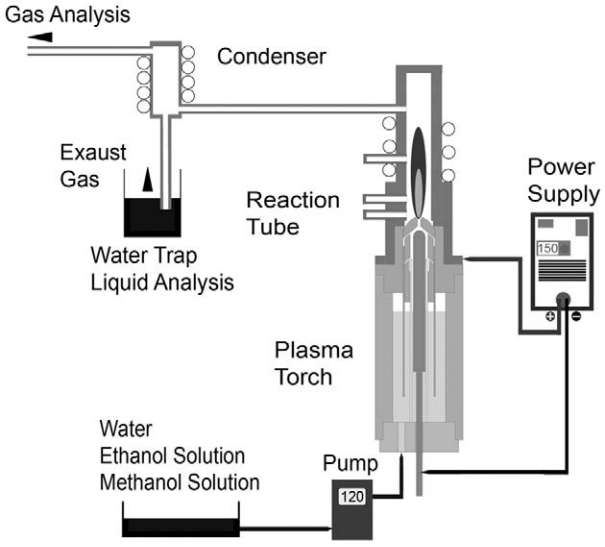

Fig. 1. Schematic of experimental apparatus.

* Corresponding author. Tel./fax: +81 45 924 5414.
E-mail address: watanabe@chemenv.titech.ac.jp (T. Watanabe).

0040-6090/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.tsf.2009.07.160

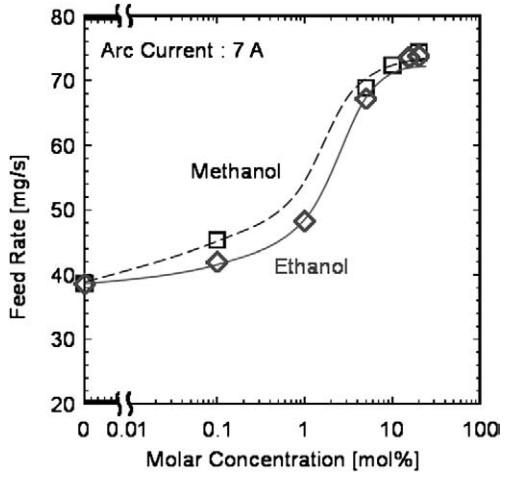

Fig. 2. Effect of molar concentration on feed rate of plasma supporting gas.

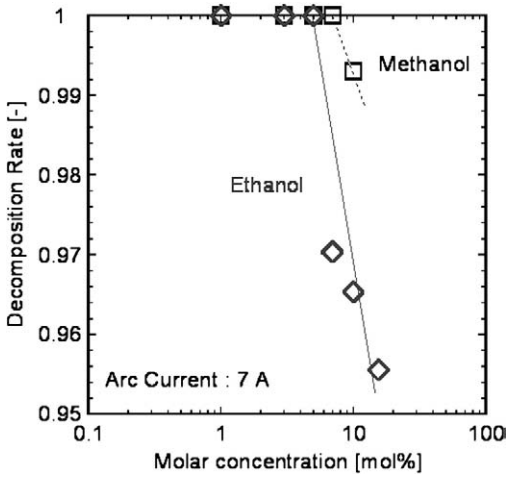

Fig. 4. Decomposition rate of methanol and ethanol solution.

converted into synthesis gas, mixture of H_2 and CO, which can be used as fuel gas or for productions of other chemicals.

2. Experiment

The schematic experimental apparatus used in this study is presented in Fig. 1. The experimental apparatus consists of a plasma torch, a reaction tube, a pump for control of feed rate, and a DC power supply. The water plasma torch set below the reaction tube is a DC non-transferred plasma arc generator of coaxial design with a cathode of hafnium embedded into a copper rod and a nozzle-type copper anode [1,2]. Methanol or ethanol used as a model substance of water-soluble organic compounds was mixed with water for plasma supporting gas. This method is more efficient than conventional injection into thermal plasmas, because water-soluble organic compounds pass through the discharge region of the water plasma. Methanol or ethanol solution was supplied into the torch with controlled feed rate. The alcohol solution was injected into the discharge region immediately after the evaporation by the extensive heat from the anode. The alcohol vapor was decomposed by the water plasma in the high-temperature zone after the discharge region.

The arc power was 0.91–1.05 kW with the arc current of 7.0 A. The measured feed rate for plasma gas produced from water, methanol solution, and ethanol solution are presented in Fig. 2. Plasma gas flow rate increases with increasing alcohol concentration because of increasing vapor pressure. Higher vapor pressure of the methanol solution causes larger feed rate of the plasma supporting gas evaporated from the methanol solution.

The decomposition mechanism of water-soluble organic compounds by water plasma was investigated using several diagnostic methods. The produced gas and liquid were separated at the condenser. The produced gas was analyzed by gas chromatography (GC) equipped with a thermal conductivity detector (SHIMADZU, GC-8A) and a quadrupole mass spectrometer (QMS, AMETEK, Dycor Proline). The produced liquid was analyzed by GC and a total organic carbon analyzer (SHIMADZU, TOC-V CSN). The excited species from methanol and ethanol during the decomposition were identified by spectroscopic diagnostics using a monochromator (Horiba Jobin Yvon, iHR550 and 500 M) equipped with a charge-coupled device (CCD) detector (1024×256 pixels).

The excitation temperature of the water plasma in the region just downstream of the nozzle exit was measured by emission spectroscopy. The emission of H_α and H_β atom lines from hydrogen were received by a CCD detector. The excitation temperatures were determined from the Boltzmann plot from hydrogen atoms.

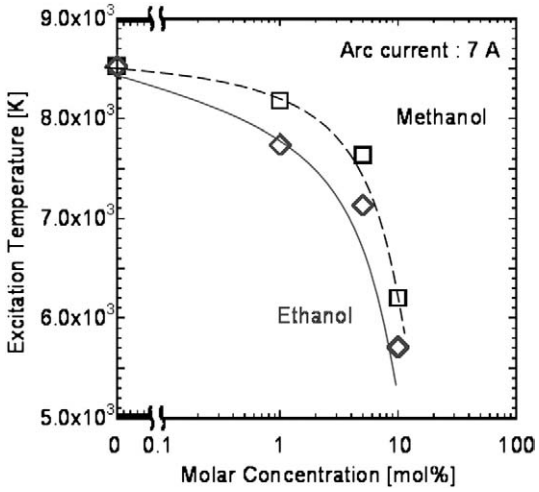

Fig. 3. Excitation temperature of plasma at exit nozzle as a function of molar concentration.

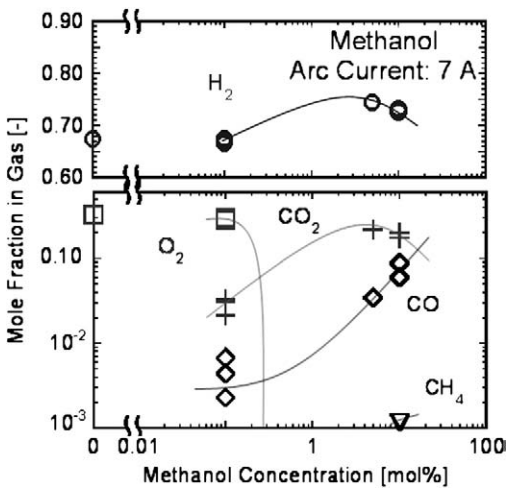

Fig. 5. Effect of molar concentration on gas composition generated from methanol solution.

Download English Version:

https://daneshyari.com/en/article/1671021

Download Persian Version:

https://daneshyari.com/article/1671021

Daneshyari.com