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Reuse of wastewater discharged from thermal-plasma decomposition of chlorodifluoromethane: Production of titanium dioxide nanopowder

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ABSTRACT

Chlorodifluoromethane, a refrigerant that will be phased out in the future, is decomposed by nitrogen thermal plasmas with a 99.99% destruction and removal efficiency discharging wastewater containing halide ions. Titanium dioxide nanotubes having a pore size less than 9 nm are produced via electrochemical anodization of titanium using wastewater containing fluoride and chloride ions generated by the decomposition of chlorodifluoromethane. Titanium dioxide spontaneously detached from the substrate into the electrolyte as the period of anodization increased due to weak adhesion between the oxide and substrate. The amount of nanopowder produced was accelerated by nitrate ions, which originated from the nitrogen plasma during the thermal decomposition process. The nitrate ions, which is naturally generated in wastewater due to nitrogen plasma act as a catalyst to accelerate the mass production of TiO_2 powder by up to two-fold, compared to that in an electrolyte without nitrate ions. The basic property originated by NaOH neutralizer of the electrolyte leads to the smooth surface morphology.

1. Introduction

Refrigeration and air conditioning technologies have developed considerably with the help of advanced refrigerants, which thereby allow safe food storage, leading to significant changes in human culture (Emani and Mandal, 2018; Anupam et al., 2011). The current refrigerants can be classified into chlorofluorocarbons (CFCs, first generation), hydrochlorofluorocarbons (HCFCs, second generation), hydrofluorocarbons (HFC, third generation), and hydrofluoro-olefins (HFO, fourth generation) depending on their atomic composition (Calm, 2008; Corberán et al., 2008). Nevertheless, after the Montreal and Kyoto protocols, these refrigerants have been gradually restricted for use in daily life because they contributed to the destruction of the earth's ozone layer (Bolaji and Huan, 2013; Kasera and Bhaduri, 2017). Among them, HCFC-22 ($CHClF_2$), which is one of the most widely used refrigerants, will soon be completely phased out. The development of technologies to recover and recycle refrigerant waste is therefore urgently required.

The United Nations Environmental Program (UNEP) collects information on the destruction technologies available for ozone depleting substances (ODSs) and providing approval for appropriate technologies (Kwon, 2014; Kim et al., 2013). Diverse plasma thermal decomposition methods have been approved because the high energy generated by plasma is sufficient to crack the stable ODS molecules into atomic substances. Lasic Jurkovic et al. reported methane partial oxidation process in pure plasma and plasma coupled with different zeolites and metal-based catalysts. Zeolite materials reduced the selectivity to organic oxygenates and promoted coking, while Pd- and Fe-based catalysts favored over-oxidation producing water and CO_2 (Lašič Jurković et al., 2019). The approved techniques mainly rely on pyrolysis in an incinerator, which are classified as methods for the direct removal of ODSs using high temperature (Huang and Buekens, 1995). In addition, a rotary kiln can be used to remove ODSs, which allows for recycling of fluoride from ODS decomposition, in the process of making cement.

The thermal plasma technique can deal with a large amount of ODSs because the reaction is finished within 1 s. Halogen by-products, which are generated during the decomposition reaction as the major components of the refrigerant, are removed through

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