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The use of black mass in spent primary battery as an oxidative catalyst for removal of volatile organic compounds

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This work synthesized spent primary batteries (SPBs)-based (SB) catalyst from the black mass (BM) of the respective SPBs of R and D companies and tested it in the complete oxidation of volatile organic compounds (VOCs) to examine its effectiveness. In particular, benzene, toluene, and *o*-xylene (BTX) were chosen as representative VOCs. In addition, the physicochemical properties of the RSB and DSB catalysts prepared from the BMs in the SPBs of R and D companies, respectively, were characterized by ICP/OES, SEM/EDX, BET, XRD, TGA, O_2-TPO, H_2-TPR, and XPS analyses. Notably, the manganese-rich DSB catalyst had a higher activity compared to the RSB catalyst. Also, the dominant crystal phases of the RSB catalyst were of C, $ZnMn_2O_4$, Mn_3O_4, ZnO, and C_2K_2, and those of the DSB catalyst were of C and MnO_2. In particular, the manganese oxide species significantly influenced the catalytic activity. Furthermore, the lattice oxygen mobility of the catalyst contributed to the VOCs complete oxidation. In effect, the BTXs were completely oxidized at less than 380 and 360 °C over the RSB and DSB catalysts, respectively, at a gas hourly space velocity of 50,000 h^{-1}.

Introduction

Since primary batteries, such as manganese and alkaline batteries, are versatile, convenient, inexpensive, and essential for electronic devices, their consumption has been steadily increasing [1]. In particular, manganese and alkaline batteries are mainly used in electronic devices requiring small power [2]. Also, they are consumed and discarded in a short time, resulting in a lot of their waste. Moreover, these spent manganese and alkaline batteries contain heavy metals, including zinc, manganese, etc. And heavy metals can pose a serious threat to humans, animals, plants, and crops. Accordingly, SPBs must be safely disposed of as they may threaten the ecosystem [3–5]. In Korea, more than 15,000 tons of spent manganese and alkaline batteries were generated in 2020 [6]. Accordingly, it is strongly necessary to recycle the spent primary batteries, which accounts for a significant portion of the discarded batteries. Recently, the resourcization of SPBs has attracted increasing attention from an economic, environmental, and technological perspective [7,8]. Meanwhile, various research had focused on the recovery of valuable metals, such as manganese, zinc, etc., from SPBs [2,9,10].

Volatile organic compounds (VOCs) are some of the main pollutants with a boiling point of less than 260 °C under room temperature and atmospheric pressure conditions [11]. The main sources of VOCs, such as chemical plants, paint factories, printing shops, food processing, etc., are varied. Since the VOCs are highly toxic and volatile, they are regarded as important air pollutants [12,13]. Furthermore, the VOCs are also a causative agent of photochemical smog and have recently been recognized as substances causing ultrafine dust [14,15]. Therefore, the VOCs must be removed from their sources without being released into the atmosphere. Various technologies have been used for the VOCs removal, including condensation [16], adsorption [17], membrane separation [18], photocatalytic decomposition [19–21], plasma oxidation [22], ozone oxidation [23–26], biological decomposition [27], combustion [28], and catalytic oxidation [29]. Notably, catalytic oxidation is economical, compact, easy to operate, and efficient among these technologies. Also, transition metals as catalysts for the VOCs

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