Zero-emission diesel combustion using a non-equilibrium-plasma-assisted MnO2 filter

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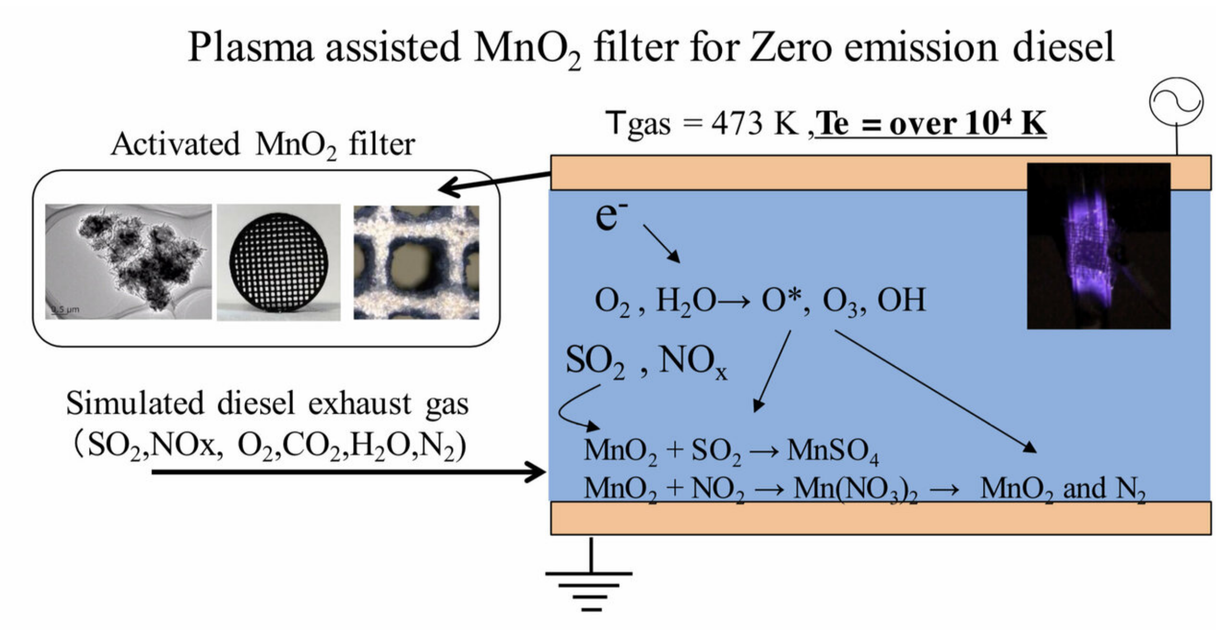
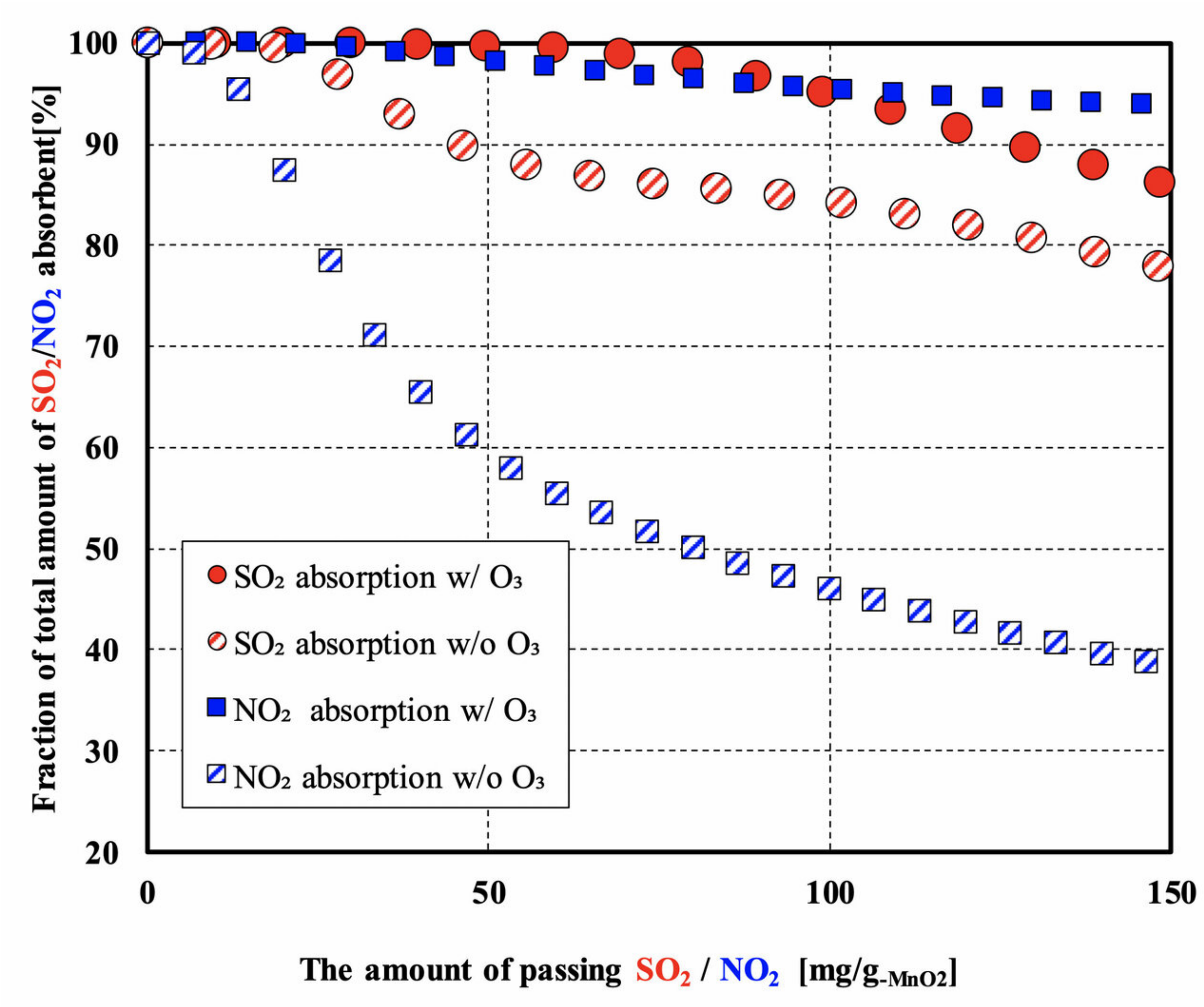


Activated chemical species (O_3, OH radicals etc.) are generated by inducing an atmospheric pressure non-equilibrium plasma. These species promote desulfurization and denitration reactions with MnO_2. In this paper, we evaluated the influence of ozone on the desulfurization and denitrification performance of an MnO_2 filter. Credit: Kanazawa University

Diesel engines are widely used in agricultural machinery, vehicles and ships because of their high thermal efficiency. The sulfur contained in diesel fuel is oxidized to sulfur dioxide by combustion. This sulfur dioxide not only harms human health but also causes deactivation of the catalysts used to treat NO_x in the exhaust stream.

This problem can be overcome by using sulfur-free fuels based on biomass or clean coal technology, or by installing a desulfurizing filter to remove sulfur oxides upstream of the NO_x catalyst. Researchers at Kanazawa university have developed a plasma-assisted MnO_2 filter that produces exhaust free of NO_x and SO_x. This technology augments the desulfurization properties of MnO_2 with the activity of ozone from an atmospheric-pressure non-equilibrium plasma (Figure 1). Activated chemical species (O_3, OH radicals, etc.) present in the plasma promote desulfurization and denitration reactions.

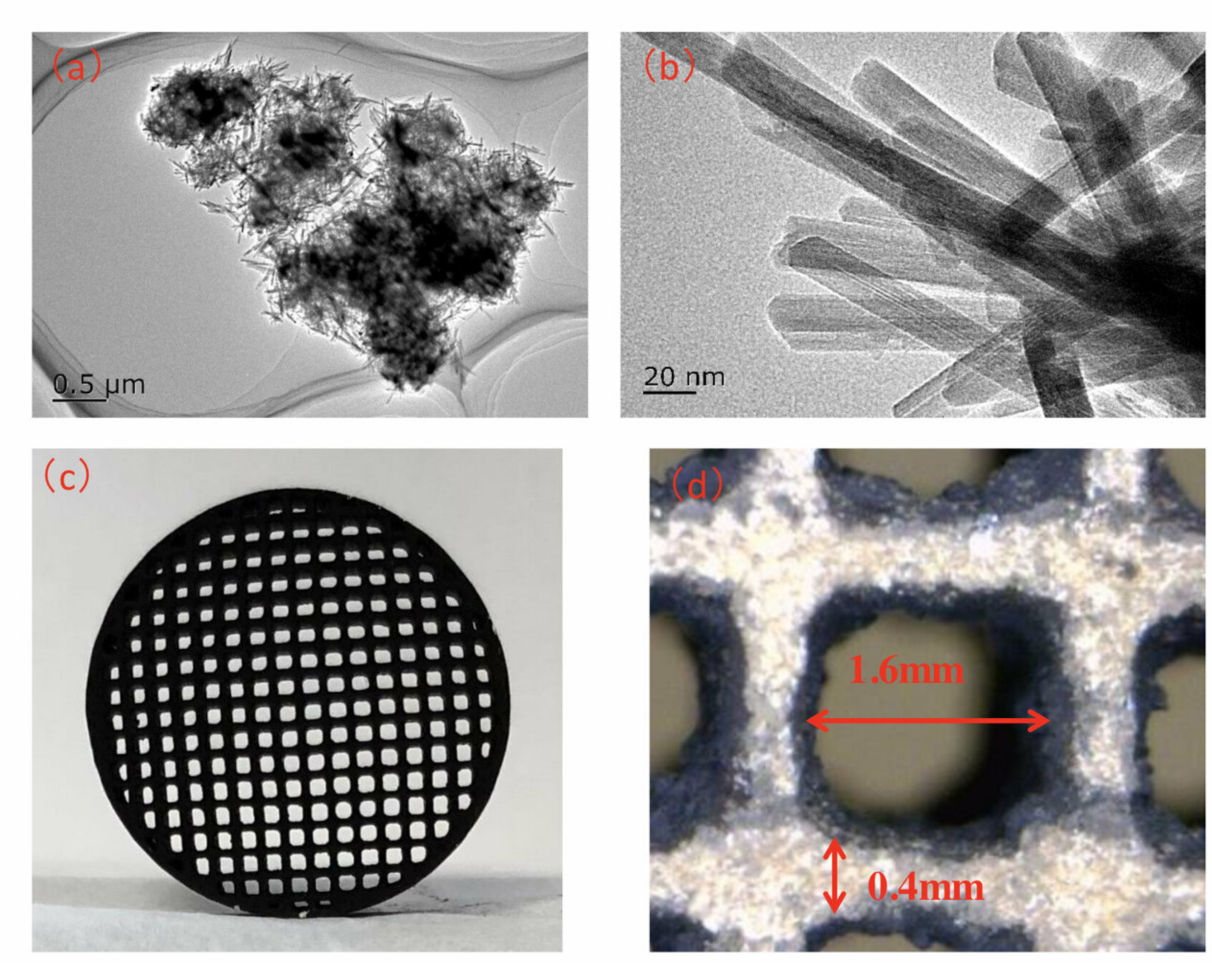
MnO_2 reacts with sulfur and nitrogen oxides to produce sulfates and nitrates, respectively. The interaction between SO_2 and NO_2 degrades the performance of MnO_2 catalysts in eliminating both species. Prof Huang of the Guangzhou Institute of Energy Conversion analyzed the MnO2 catalyst material after exposure to simulated exhaust gas containing both SO_2 and NO_2 and found that both manganese nitrate and manganese sulfate were produced.



Ozone generated in an atmospheric-pressure non-equilibrium plasma was passed through the MnO_2 filter together with simulated exhaust gas. The simulated exhaust gas consisted of 500 ppm SO_2, 500 ppm NO_2,10wt% O_2, 6wt% CO_2, an N_2 base, and 50 ppm O_3 (when plasma is induced). The MnO_2 was supported on an alumina honeycomb filter and the flow conditions (space velocity of 10^4 $h^{?1}$) mimicked typical vehicle exhaust streams and filter dimensions. Credit: Kanazawa University

We evaluated the impact of ozone on the performance of the catalyst for SO_2 and NO_2 removal (Figure 2). An atmospheric-pressure non-equilibrium plasma was generated by the dielectric barrier discharge method. The performance of the catalyst in eliminating both SO_2 and NO_2 was improved by the introduction of ozone at a low concentration of about 50 ppm. The enhancement in NO_2 elimination was particularly notable. The introduction of ozone seems to give a reaction to reduce nitrogen oxides to nitrogen. At the initial stage of the reaction, over 99% of SO_2 and NO_2 were removed from the exhaust stream. The Kanazawa University researchers, led by Yugo Osaka, demonstrated for the first time that zero emissions of NO_x can be achieved even in the presence of sulfur oxides by using a plasma-assisted MnO_2 filter. The plasma-assisted filter seems to augment the elimination of SO_2 because of SO_3 generation and also reduce nitrogen oxides to nitrogen.

These findings are expected to be widely applicable in the purification of exhaust from diesel engines using sulfur-containing fuels. We have clarified the mechanism by which the induction of the non-equilibrium plasma augments the performance of the MnO_2 filter. We hope to spur further development of plasma-assisted MnO_2 filters and thus allow for a greater diversity of fuels to be used without adversely impacting air quality.



TEM images (a, b) of HSSA MnO_2 (MnO_2 having a high specific surface area of about 300 m^2/g) and photographs (c, d) of the HSSA MnO_2 filter supported on alumina honeycomb used in these experiments. MnO_2 was laminated onto the alumina honeycomb substrate by the dip coating method. The packing density of MnO_2 was 50 g/L of filter Credit: Kanazawa University

More information: Yugo Osaka et al, Basic study on exhaust gas purification by utilizing plasma assisted MnO_2 filter for zero-emission diesel, *Separation and Purification Technology* (2018). DOI: 10.1016/j.seppur.2018.12.077

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