論文 / 著書情報
Article / Book Information

題目(和文)	電子顕微鏡タイムラプス可視化を用いたスス酸化を伴うディーゼル微粒子フィルター再生に関する研究
Title(English)	A study on diesel particulate filter regeneration process with soot oxidation through time-lapse visualization using electron microscopes
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種別(和文)	論文要旨
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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	Mechanical Engineering	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （Engineering）
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要旨（英文800語程度）

Thesis Summary (approx.800 English Words)Chapter 1: Soot emission in exhaust gas from diesel engines is a cause of respiratory diseases and adverse effects on air quality. Among extensive studies of the soot trapping process, DPF regeneration via soot oxidation is rather challenging due to its high operating temperature and associated chemical reactions. An aim for development of an after-treatment system is to attain fast oxidation of accumulated soot at low temperatures. This will result in considerable energy savings and reduce potential damage to the filter. To propose new strategies for efficient regeneration, understanding of physical characteristics, and chemical kinetics of soot oxidation is required to provide visual and kinetic inspections of phenomena routinely occurred in the real DPF system.

Chapter 2: two types of soot generated from an arc-discharge process, and diesel fuel-lamp flame were benchmarked with soot generated from a diesel engine. The lamp soot and the engine soot exhibit similar TGA derived mass-conversion rates, under oxidation conditions typically encountered in practical DPF active regeneration process. The result is consistent with their similarity in nanoscale primary particles, observed by TEM. The arc-discharged soot exhibits a unique conversion rate among all samples. Its nanostructure exhibits graphitic long carbon lamellae, with not as well defined as spherical primary particles. After oxidation, shrinking core of the lamp soot primary particles was quantitatively measured. Measurement of the arc-discharged soot shrinkage was not possible in nanoscale but was visually inspected in micron-scale using FE-SEM. In this chapter, the diesel lamp soot is concluded as a better representative for diesel engine soot over the arc-discharged soot.

Chapter 3: pictures of DPF regeneration process have been revealed, for the first time, via time-lapse particle-scale visualization using FE-SEM. Diesel lamp soot was used according to the conclusion of chapter 2. Soot oxidation was initiated with shrinkage of the soot dendrite-microstructures. The shrinkage creates a more packed soot cake layer, decreasing permeability of working gas flow. Thereby, partially increasing pressure drop across the DPF. Shrinking core of the spherical soot primary particles was shown to be an initiation of shrinking soot cake layer. Shrinkage of the packed soot cake subsequently resulted in small cracks throughout the top surface of soot cake. This was followed by fragmentation of partially oxidized soot cake, decreasing pressure-drop across the filter. The fragmentation was caused by locally higher flow velocities passing through the surface-pore areas, as surface pore soot locally pulled from DPF substrate. As oxidation progressed, increasing differences in attraction forces between soot to soot, and soot to Si-C substrate are proposed as a factor causing separation between soot cake layer and Si-C DPF wall.

Chapter 4: To further discuss soot oxidation kinetics in DPF regeneration, temperature programmed oxidation (TPO) experiments were performed in miniaturized DPFs. In catalyzed DPF, with thick soot cake layer, the Arrhenius plot showed an increase in estimated activation energy for oxidation at

temperature >500° C. This was due to transformation of oxidation from soot in catalyst proximity to soot layer further away from the catalyzed substrate. In bare-type DPF, thick soot cake layer also resulted in 15% more of remaining soot mass than the case with thin soot cake, at temperature >600° C. This is attributed to aggregations of partially oxidized soot residuals, remained on DPF walls, previously reported in chapter 3. The residuals were characterized as graphitized carbons; therefore, they are stable to oxidation and can deteriorate the service-lifetime of DPFs. With presence of NO_2 in reactant gas, soot oxidation range was extended to 50° C lower temperature, moreover, the estimated activation energy for soot oxidation was decreased by 30%. This implies catalytic effect due to NO_2, even with using bare-type DPF.

Chapter 5: Effect of NO_2 on soot oxidation was further investigated by considering the oxidation rate and soot physical nanostructure. The diesel soot was partially oxidized under different reactant gas conditions of 10% O_2 with and without 500 ppm NO2 at 425° C. After 40% mass conversion, hollow-interior formation of soot primary particles due to internal burnout is commonly observed for both cases of reactant gas. However, the degree of internal burnout is less when soot was exposed to NO_2+O_2. Using fringe analysis, preferential loss of short and curved carbon fringes was measured to be decreased with the presence of NO_2. Smaller and more curved fragments comprise a greater number of edge-site carbon atoms compared to basal planes. Thereby, NO_2 appears to act as an accelerator, increasing oxidation of the edge-site atoms. The accelerated edge-site oxidation is supportive evidence for the catalytic effect caused by NO_2 at low temperatures discussed in chapter 4.

Chapter 6: The shrinkage of soot, due to oxidation, discloses the surface pore area, establishing an inhomogeneous flow of the reactant gas passing through and between the clean surface pores and aggregated soot remaining on the wall. In the bare-type DPFs, a thick soot cake layer results in a significantly higher percentage of soot mass remaining compared to that of a thin soot cake layer. The soot residuals are more difficult to gasify compared to untreated diesel soot. The enhancement of soot oxidation by the presence of NO_2 in the exhaust gas was due to a catalytic effect. Carbon fringe analysis revealed the role of NO_2 to preferentially attack edge-site carbon atoms, suggesting a relationship between soot nanostructures and oxidation kinetics.