Catalytic combustion of diesel soot particles on potassium and sodium titanates

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Potassium and sodium titanates have been synthesized and characterized, and, the activity for oxidation of diesel soot particles evaluated by TG-DTG. The XRD patterns, DRIFT spectra and XRF data reveal the formation of sodium and potassium titanates. The formation of K$_2$Ti$_3$O$_7$ and Na$_{1-x}$Ti$_5$O$_{12-x}$ phases are observed for K$_2$O and Na$_2$O loadings greater than 33 %. The BET-surface area and pore volume results show the non-porous characteristics of the materials. The soot oxidation characteristics of K and Na titanates show that the complete combustion of diesel soot can be obtained between 400 and 415 °C. Potassium and sodium titanates exhibit greater activity than the high surface area hydrated titania, showing the enhanced soot-catalyst contact characteristics of the titanates and also the ability of the catalysts to release active oxygen species. The results show that titania can be a suitable support for K and Na, particularly for the combustion of soot.

Keywords: Catalysts, Oxidations, Combustion, Diesel soot oxidation, Titania, Potassium titinate, Sodium titinate, Catalytic combustion

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Diesel soot particulates and nitrogen oxides are harmful components in diesel exhaust\(^1\).\(^2\). Diesel engine exhausts is also composed of sulfates and heavy hydrocarbons, which are derived from lubricating oil and unburnt fuel. In particular, soot particulates caused by incomplete combustion of diesel fuel, increase the hydrocarbons, which are derived from lubricating exhausts is also composed of sulfates and heavy harmful components in diesel exhausts.

Diesel soot particulates and nitrogen oxides are harmful components in diesel exhaust. In particular, soot particulates caused by incomplete combustion of diesel fuel, increase the degree of air pollution that causes offensive odours and are harmful to human health. Thus, it is essential to develop catalysts and technologies for abatement of the soot particulates. A soot oxidation catalyst (SOC) usually combines high active metals or metal oxides with supports, including zeolites and metal oxides. A variety of catalysts have been examined for diesel soot oxidation, including Pt\(^3\), molten salts\(^4\), perovskites\(^5\), zeolites\(^6\), and different metal oxides\(^7,9\). There are reports demonstrating soot oxidation over PbOx/CoOx\(^10\), CsNO$_3$/ZrO$_2$\(^11\), Mo/Al$_2$O$_3$\(^12\), MnOx\(^13\) and CeO$_2$\(^14\). Most of the oxidation catalysts sold in international markets are noble metal based (Pt, Pd), which are expensive due to low abundance. In many cases, the catalytic activity of the support is crucial. For example, a few reports\(^15\) suggest the poor performance of titania as a support for diesel soot oxidation. van Doorn et al.\(^16\) studied the catalytic role of several metal oxides in soot combustion by O$_2$ and concluded that Al$_2$O$_3$ and SiO$_2$ had no catalytic effect, while TiO$_2$ and ZrO$_2$ had moderate activity, and, CeO$_2$, La$_2$O$_3$, and V$_2$O$_5$ exhibited substantial activity for soot combustion.

Peralta et al.\(^17\) suggested that K in K/CeO$_2$ catalyst may act to form a carbonate-type intermediate with partially oxidized soot. These studies confirm that the catalysts containing alkali metals are active for soot oxidation. Hence, there is a strong reason to develop a catalyst for diesel particulate filter (DPF) that displays good activity at lower temperatures, better stability, relatively low cost and most of all is environmentally benign. Potassium compounds show considerable activity toward diesel soot combustion\(^18\)-\(^21\). In view of the economic and environmental concerns, it is advisable to use elements available in abundance such as O, Si, Al, Na and K. Many catalytic systems developed so far are sensitive to sulfur and are irreversibly deactivated by sulfur compounds in diesel exhaust, even at low concentrations\(^22\)-\(^23\). Alkali metal titanates are used as precursor for the preparation of the derivatives of fibrous titanium dioxide which are applied in photo catalyst, gas-sensors and solar cells\(^24\),\(^25\). There are reports describing the preparation of sodium and potassium titanates by hydrothermal method, solid-state and flux method\(^26\)-\(^31\).

We report herein the preparation of sodium and potassium titanates by condensation followed by calcination and their catalytic activity for diesel soot oxidation in air. The reason for selecting titania as the support is that (i) the reported studies show that titania is not an effective support for soot oxidation,
(ii) alkali titanates are thermally more stable than silicates and aluminates, and, (iii) titania based catalysts are not sensitive to sulphur poisoning.

**Materials and Methods**

Titanium oxysulphate (Aldrich), Carbon CDX-975 (Columbian Chemicals Company), Carbon Vulvan XC-72 (Cabot Corporation, USA), potassium hydroxide (Qualigens) and sodium hydroxide (Qualigens) were used without further purification. Doubly distilled water was used as a solvent.

**Preparation of alkali titanates**

An aqueous pulp of hydrated titania (HT) containing a small amount of combined and/or adsorbed sulphuric acid, obtained by hydrolytic precipitation from a titanium oxysulphate solution, was treated with varying quantities of NaOH and heated for three hours at a temperature of about 100 °C. The reaction was carried out under atmospheric pressure with continuous stirring. The reaction mass obtained at the end of three hours was filtered and washed with additional water to remove all the sulfates and unreacted sodium hydroxide. The product obtained was dried at 100 °C for 12 hours and thereafter calcined at 750 °C for 1 hour. Similar procedure was followed for the preparation of potassium titanates using HT and KOH (compositions as given in Table 1). The obtained potassium and sodium titanates were examined as catalysts for oxidation of diesel soot.

Wide-angle XRD patterns for the calcined materials were obtained on a Rigaku Miniflex II, using Cu-Kα irradiation. SEM studies were carried out on a FEI Quanta 200 electron microscope. The composition of these catalysts was analysed using a Rigaku XRF-Primini spectrometer. The BET-specific surface area and porosity were measured using Micromeritics ASAP-2020 surface area and porosity analyzer respectively. The DRIFT spectra for the samples were recorded using a Bruker Tensor-27 system.

**Preparation of soot-catalyst samples for soot oxidation study**

The soot was collected from the exhaust of the diesel vehicles. After collecting the soot from the vehicles, it was dried in an oven for 24 h at 120 °C. The soot thus obtained, having a surface area of 47 m²/g, was used for preparing mixtures of soot and catalyst.

Each catalyst was mixed with diesel soot at a weight ratio of 1:0.1 for catalyst and soot. The soot-catalyst samples with higher soot content were also prepared and studied. The catalyst and soot were mixed in a vial with a spatula before being transferred to a crucible. This mixing ensured a loose soot-catalyst contact. Soot-catalyst tight contact mixtures were obtained by careful grinding in an agate mortar. Although the tight contact combustion is too rigorous to compare with what is essentially possible in a soot trap, this study forms a basis for activity screening.

**Catalytic activity test**

The loose and tight contact catalyst-diesel soot mixtures have been evaluated by Perkin-Elmer TG-DTG for combustion of the soot. The samples were heated from 40 to 600 °C at a rate of 5 °C/min using 50 ml/min. air as the combustion gas to identify the soot oxidation potential of the sodium and potassium titanate samples. The stability of the catalysts were tested by running repeated experiments where the used catalyst was further mixed with fresh soot and re-tested. The activity of a catalyst is defined by the combustion peak maximum, which is the temperature of the TGA curve where 100 % (T_max) of the soot was oxidized. To verify the reproducibility of results, all TG-DTG experiments were repeated twice. The combustion onset temperature, T_{so}, and T_{max} values showed a variation of less than 5 °C for repeated measurements.

**Results and Discussion**

**XRD patterns of sodium and potassium titanate**

The XRD patterns of the sodium titanate (NT) and potassium titanate (KT) samples prepared with various concentrations of Na₂O and K₂O are shown in Figs 1 and 2. The XRD patterns measured for calcined NT and KT samples show that the XRD data are consistent with the data reported in JCPDS 76-0686 for NT and JCPDS 76-1682 for KT respectively. The peaks at 2θ of 10.5, 12, 12.6, 34.2, 39 and 40.8 are characteristic of sodium titanates. The peaks at 2θ of 13.6, 19, 29.2, 32, 35, 38.2, 41.7 and 47.9 are characteristic of potassium titanates. The NT prepared with 33.3 % and 41.6 % of Na₂O shows pure phases of NT. Nevertheless, the sample NT-2 prepared with 23.2 % of Na₂O shows mixed phases of anatase and NT which is substantiated by the presence of anatase peak at a 2θ of 25.5. The sample prepared with 10.4 % Na₂O does not show the presence of NT, indicating that 33 % of Na₂O may be the optimum or minimum quantity to produce a pure phase of NT. The XRD patterns obtained for NT samples calcined at 750 and 900 °C show no significant enhancement in the intensity of peaks demonstrating...
that the optimum calcination temperature is 750 °C. The XRD patterns obtained for KT presented in Fig. 2 show pure phases of KT. Furthermore, enhanced intensities of peaks with increase in loading of K₂O from 34.5 % to 42.1 % are observed. The formation of K₂Ti₂O₅ and Na₁₆Ti₁₀O₂₈ phases are observed for K₂O and Na₂O loadings greater than 33 %.

**Composition and surface analysis**

The composition, crystallite size, BET-surface area, and pore volume of the NT and KT samples are given in Table 1. The composition determined by XRF shows the absence of sulphur in all the samples. About 1.4-2.1 wt. % loss of Na₂O and K₂O in the respective titanate samples demonstrates the removal of sulphates as sodium and potassium sulphates. The obtained composition indicates the non-removal of alkali metals through the process of washing and filtration. The crystallite size of the samples was calculated by Scherrer equation. The data showed values of 19-22 nm for sodium titanates and 31-33 nm for potassium titanates. The higher crystallite size obtained for potassium titanates over sodium titanates could be due to rigorous sintering. This fact was demonstrated by the apparent SEM images and greater intensity of XRD peaks observed for potassium titanates. The BET-surface area and pore volume values were found to decrease with increasing sodium and potassium contents of the titanate samples. The HT with a specific surface area of 277 m²/g was sintered to 46 m²/g after calcination at 750 °C. The objective of using HT for the synthesis of KT and NT was to obtain high surface area titanates. Nevertheless, the presence of potassium and sodium ions in titania stimulates a severe sintering as shown by the small BET-surface area values (1.5-3.2 m²/g). This larger sintering is in accordance with the increase of the crystallite size as shown in

<table>
<thead>
<tr>
<th>Samples</th>
<th>Na₂O/K₂O (wt.%)</th>
<th>TiO₂ (wt.%)</th>
<th>Crystallite size (nm)</th>
<th>BET - surface area (m²/g)</th>
<th>Pore vol. (cm³/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrated titania (HT)</td>
<td>—</td>
<td>99.5</td>
<td>6.9</td>
<td>275</td>
<td>0.33</td>
</tr>
<tr>
<td>10.4 % Na₂O/TiO₂ (NT-1)</td>
<td>10.4 (Na₂O)</td>
<td>89.6</td>
<td>19.2</td>
<td>3.2</td>
<td>0.024</td>
</tr>
<tr>
<td>23.2 % Na₂O/TiO₂ (NT-2)</td>
<td>23.2 (Na₂O)</td>
<td>76.8</td>
<td>20.4</td>
<td>2.7</td>
<td>0.019</td>
</tr>
<tr>
<td>33.3 % Na₂O/TiO₂ (NT-3)</td>
<td>33.3 (Na₂O)</td>
<td>66.7</td>
<td>21.2</td>
<td>2.1</td>
<td>0.015</td>
</tr>
<tr>
<td>41.6 % Na₂O/TiO₂ (NT-4)</td>
<td>41.6 (Na₂O)</td>
<td>58.4</td>
<td>22.1</td>
<td>1.8</td>
<td>0.013</td>
</tr>
<tr>
<td>34.5 % K₂O/TiO₂ (KT-1)</td>
<td>34.5 (K₂O)</td>
<td>65.5</td>
<td>30.7</td>
<td>1.7</td>
<td>0.011</td>
</tr>
<tr>
<td>42.1 % K₂O/TiO₂ (KT-2)</td>
<td>42.1 (K₂O)</td>
<td>57.9</td>
<td>33.1</td>
<td>1.5</td>
<td>0.008</td>
</tr>
</tbody>
</table>

*Composition determined by XRF.*
Table 1. The addition of potassium and sodium ions to TiO$_2$ effects the stabilization of the titania by forming stable phases such as K$_2$Ti$_2$O$_5$ and Na$_{16}$Ti$_{10}$O$_{28}$.

**Morphology of sodium and potassium titanates**

Figure 3 shows the SEM images obtained for the potassium titanate (KT-2) and sodium titanate (NT-4) samples calcined at 750 °C for 1 hour. The flat surfaces of facets with different sizes indicate the typical rod-like morphology for KT and NT samples which may have originated from the layered structure in which the structural units consisting of four TiO$_6$ octahedra share edges at one level and form rods. The length of the rods for KT and NT were found to be less than 5 µm. A closer analysis of the SEM images demonstrates that the NT and KT samples are agglomerated into bundles.

**DRIFT spectra**

The DRIFT spectra of sodium titanate (NT), potassium titanate (KT) and hydrated titania (HT) samples calcined at 750 °C are presented in Fig. 4. The HT calcined at 750 °C for 1 h shows a broad peak in the regions of 660-1360, 3000-3600 cm$^{-1}$ and a sharp peak at 1640 cm$^{-1}$. The NT prepared with 10.4 wt. % loading of Na$_2$O shows characteristic peaks at 985, 1170, 1466 and in the region of 2070-2500 cm$^{-1}$. A similar pattern of IR absorptions is also obtained for NT prepared with higher quantity of Na$_2$O. The increase in concentration of Na$_2$O in NT decreases the intensity of absorptions in the region of 660-1360 and at 1640 cm$^{-1}$, which may be due to dissimilarities in the structure. Furthermore, greater absorptions were observed in the region of 600-2500 cm$^{-1}$ which may be due to the formation of bonds between Ti-O and Na-O/K-O. The DRIFT spectra for NT and KT samples reveal a broad
absorption peak in the region of 3600–3000 cm\(^{-1}\), displaying its greater affinity for water absorption than HT. The spectra obtained for KT is different from NT, showing broad absorption spectrum in the region of 1230-1800 cm\(^{-1}\) which differs from the titania precursor (HT) used for the synthesis of NT and KT. The DRIFT spectra obtained for the samples indicate that the molecular environment is different for KT and NT. The evaluation of DRIFT spectra of HT, NT and KT demonstrates that the obtained NT and KT are in different forms and have the structure of \(\text{K}_2\text{O/Na}_2\text{O.nTiO}_2.\text{nH}_2\text{O}\).

Soot oxidation

In order to systematically study the effect of alkali metals (Na and K) on titania, the NT and KT samples were prepared with varying quantities of Na\(_2\)O and K\(_2\)O. The effect of temperature on the individual tight contact soot-catalysts mixtures was measured by TG-DTG. The effect of 10 % loading of diesel soot on hydrated titania (HT), sodium and potassium titanate samples calcined at 750 °C are presented in Table 2. The combustion onset temperature, \(T_{50}\) and \(T_{\text{max}}\) values for the soot oxidation on various catalyst samples are shown in Table 2. The HT used for the preparation of sodium and potassium titanates shows a \(T_{\text{max}}\) of soot at 600 °C. The \(T_{\text{max}}\) was found to decrease with increase in sodium content of the NT samples and lowest temperature was attained (415 °C) for the NT-4 sample containing 41.6 wt. % Na\(_2\)O. Similarly, a \(T_{\text{max}}\) of 400 °C was obtained for the KT-2 sample loaded with 42.1 wt. % K\(_2\)O. Higher loadings (>43 %) of Na\(_2\)O and K\(_2\)O in titania could not effectively be prepared due to difficulties encountered at the preparation stages of filtration and drying. The combustion onset temperature for KT-2 is 273 °C and for NT-4 it is 280 °C, which is about 200 °C lower than that for HT.

The \(T_{50}\) and \(T_{\text{max}}\) for KT-2 and NT-4 are also about 200 °C lower than the value for HT. The catalytic performance of NT and KT samples is found to notably depend on the quantity of sodium and potassium ions. The highest activity of soot oxidation was obtained for the catalyst containing the maximum quantity of Na\(_2\)O and K\(_2\)O. The results show that alkali metals are effective in promoting catalytic soot oxidation. Alkali metals were found to play different roles in these catalysts; increasing the catalyst-soot contact by increasing surface mobility of alkali metal ions favors the oxidation of soot by consuming the carbon to form carbonate species during soot combustion. It is a known phenomenon that for a solid-solid reaction, physical contact between the two solids is essential. The potassium and sodium titanates exhibit greater soot oxidation activity than the high surface area hydrated titania, which may be attributed to the formation of potassium and sodium titanates. Although potassium titanates are found to have lower surface area than sodium titanates, they surprisingly show greater soot oxidation activity than sodium titanates. The reason for this, however, needs to be investigated. These results, however, do not agree with the results of Yuan et al.\(^{33}\), which explains that the improved surface area of the catalyst can enhance the rate of combustion of soot. Nevertheless, there are reports which demonstrate the promoting effect of potassium for soot oxidation on other catalysts\(^{34}\). Mul et al.\(^{35}\) proposed that the high activity of Cu/K/Mo/Cl catalysts, is due to volatility of these compounds. Similarly, Serra et al.\(^{36}\) showed that the presence of eutectic liquid phases appreciably improved the contact between the catalyst and soot and thereby enhanced the activity of Cu–K–V based catalysts.

Considering these results, the effectiveness of potassium and sodium titanate may not be attributed to the results of surface area, as the value is too small, and furthermore, the ceramic characteristics of titanates are apparent from the nitrogen adsorption-desorption isotherms. However, the hypothesis of volatility and melting point can not be ignored. The alkali titanates have lower melting points (940–1200 °C) than titania (~1800 °C) and the volatility of potassium and sodium is postulated to improve the contact between soot and catalyst, which possibly led to the lowering of combustion temperature of the soot.

The NT and KT samples with stoichiometric quantities of alkali metal oxide and titania (NT-4 and

### Table 2 — Effect of 10 % loading of diesel soot on hydrated titania and sodium and potassium titanate samples calcined at 750 °C. [10.4 % Na\(_2\)O/TiO\(_2\) (NT-1), 23.2 % Na\(_2\)O/TiO\(_2\) (NT-2), 33.3 % Na\(_2\)O/TiO\(_2\) (NT-3), 41.6 % Na\(_2\)O/TiO\(_2\) (NT-4), 34.5 % K\(_2\)O/TiO\(_2\) (KT-1), 42.1 % K\(_2\)O/TiO\(_2\) (KT-2)]

<table>
<thead>
<tr>
<th>Sample</th>
<th>Onset (°C)</th>
<th>(T_{50}) (°C)</th>
<th>(T_{\text{max}}) (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT</td>
<td>473</td>
<td>541</td>
<td>599</td>
</tr>
<tr>
<td>NT-1</td>
<td>390</td>
<td>449</td>
<td>514</td>
</tr>
<tr>
<td>NT-2</td>
<td>329</td>
<td>411</td>
<td>468</td>
</tr>
<tr>
<td>NT-3</td>
<td>295</td>
<td>367</td>
<td>424</td>
</tr>
<tr>
<td>NT-4</td>
<td>280</td>
<td>344</td>
<td>413</td>
</tr>
<tr>
<td>KT-1</td>
<td>286</td>
<td>354</td>
<td>416</td>
</tr>
<tr>
<td>KT-2</td>
<td>273</td>
<td>335</td>
<td>401</td>
</tr>
</tbody>
</table>
KT-2) show good performance at a 10 % loading of soot. The $T_{\text{max}}$, $T_{50}$ and combustion onset temperature of the diesel soot on the catalysts were found to decrease with the decreasing loading of diesel soot.

**Thermal studies**

Figure 5 shows the TG-DTG profiles obtained for 10-30 % diesel soot loaded on NT-4. The DTG curve obtained for the 10 % DS loaded on NT-4 shows three peaks at 85, 220 and 415 °C. A loss of 4.4 wt. % is obtained up to 125 °C which is also obtained for the catalyst sample alone, which may be attributed to the removal of adsorbed water on the catalyst. The third weight loss curve is observed in the temperature range of 367-460 °C, which is due to oxidation of diesel soot. The NT-4 sample loaded with 20 and 30 wt.% DS shows two weight loss peaks at about 80 and 420 °C. The intensity of peak and weight loss due to soot oxidation at about 420 °C is found to increase with the increase in loading of DS. The weight loss at about 420 °C is 7.2 wt. % for DS-10 %, 16.7 wt. % for DS-20 % and 23 % for DS-30 % respectively.

The TG-DTG curves obtained for 10-30 % diesel soot loaded on KT-2 are presented in Fig. 6. The DTG

![Fig. 5 — Effect of combustion of varying diesel soot (DS) loadings on NT-4. [a, DS-10 %; b, DS-20 %; c, DS-30 %].](image)

![Fig. 6 — Effect of combustion of varying diesel soot (DS) loadings on KT-2. [a, DS-10 %; b, DS-20 %; c, DS-30 %].](image)
Curves obtained for the various loadings of DS demonstrate a wide curve for 10-20 % loading of DS. The catalyst loaded with 30 % of DS shows a sharp curve at 400 °C. The shapes of the peaks show that at lower DS loadings (≤ 20 %) the oxidation starts at lower temperatures than at higher loadings. The KT-2 sample loaded with 2030 wt. % DS shows two weight loss peaks at about 165 and 400 °C. The weight loss due to soot oxidation at about 400 °C is found to increase with increase in the loading of DS, which is analogous to the trend obtained on NT-4. The weight loss at about 400 °C is 8.3 wt. % for DS-10 %, 16.8 wt. % for DS-20 % and 21 wt. % for DS-30 % respectively. The DTG curve obtained for the 10 % DS loaded on KT-2 shows two peaks at 139 and 394 °C. A loss of 8.3 wt. % is obtained up to 200 °C, which is also obtained for the pure catalyst. This may be attributed to the removal of adsorbed water on the catalyst.

The heat of reaction is anticipated to alter the difference between the sample temperature and furnace temperature and thereby affect the thermogram. An exothermic change in soot oxidation causes the sample temperature to lead the furnace temperature. The DS loadings ≥ 30 % result in a reaction run away generated by soot combustion. An endothermic change typically makes the sample temperature lag behind the furnace temperature. The TG-DTG profiles obtained for soot oxidation performed with ≤ 20 % DS on KT-2 and NT-4 show the sample temperature to lag behind the furnace temperature. Hence, to avoid the masking of soot oxidation results by energy and mass transport phenomena, a DS loading of 10 % is used in this study.

Soot oxidation with composite diesel soot

The diesel soot oxidation performance was studied on NT and KT using the composite diesel soot collected from a few vehicles. In order to evaluate the oxidation performance of diesel soot on NT and KT, the study of oxidation of commercial carbons such as Carbon CDX-975 and Carbon Vulvan XC-72 was also performed on NT-4 and KT-2 at 10 % loading. The results obtained for the combustion of Carbon CDX-975, Carbon Vulvan XC-72, and diesel soot on KT-2 and NT-4 samples are presented in Table 3. The trend of $T_{\text{max}}$, $T_{\text{so}}$ and combustion onset temperature follows the order: Carbon CDX-975 > Carbon Vulvan XC-72 > diesel soot on KT-2 and NT-4 samples. The combustion of CDX-975 is complete at 468 °C and 432 °C for NT-4 and KT-2 respectively. Similarly, VXC-72 shows complete combustion on KT-2 at 419 °C, which is about 30 °C lower than on NT-4. The results obtained show that KT-2 is a more effective catalyst for soot oxidation than NT-4.

The XRF measurements of NT and KT samples calcined at 900 °C for 2 h show a weight loss of 11 % Na2O and 9.8 % K2O while the samples calcined at 750 °C for 6 h show a weight loss of 5.2 wt. % Na2O and 4.5 % K2O. Nevertheless, the temperature is not anticipated to go beyond 550-600 °C in the diesel exhaust. The continuous combustion of eight runs at 10 % loading of diesel soot on the NT-4 and KT-2 samples shows about 11 % deactivation of the catalyst due to the elimination of alkali metals. The KT-2 and NT-4 samples calcined at 900 °C show an elevation of about 10 °C in the combustion onset temperature, $T_{\text{so}}$ and $T_{\text{max}}$. This could be attributed to the loss of Na2O and K2O on calcination at 900 °C. The loading of 10 % diesel soot in KT-2 and NT-4 by loose contact mixing shows an elevation of about 140 °C on the combustion onset temperature, $T_{\text{so}}$ and $T_{\text{max}}$. This indicates that physical contact between soot and catalyst is essential for lowering the combustion temper.

The mechanism for soot oxidation over potassium and sodium titanates may not be explained on the basis of redox mechanism as reducible species are not present in the catalyst. However, the interface between the soot and active sites of the catalyst is possibly a reason for the effectiveness of these catalysts. In addition, the mobility of the partially burnt soot particles is anticipated to generate new interfaces on the surface of the catalyst, which can accelerate the complete combustion at lower temperatures. Potassium and sodium titanate samples interact with C and O2 at about 300 °C and the reaction is anticipated to occur via a carbonate-type intermediate, which is formed by consuming the carbon from the diesel soot. Thereafter, the

<table>
<thead>
<tr>
<th>Sample</th>
<th>Onset (°C)</th>
<th>$T_{\text{so}}$ (°C)</th>
<th>$T_{\text{max}}$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KT-2 (CDX)</td>
<td>303</td>
<td>378</td>
<td>431</td>
</tr>
<tr>
<td>KT-2 (VXC)</td>
<td>295</td>
<td>362</td>
<td>419</td>
</tr>
<tr>
<td>KT-2 (DS)</td>
<td>273</td>
<td>335</td>
<td>401</td>
</tr>
<tr>
<td>NT-4 (CDX)</td>
<td>326</td>
<td>401</td>
<td>468</td>
</tr>
<tr>
<td>NT-4 (VXC)</td>
<td>315</td>
<td>388</td>
<td>450</td>
</tr>
<tr>
<td>NT-4 (DS)</td>
<td>280</td>
<td>344</td>
<td>413</td>
</tr>
</tbody>
</table>
intermediate is decomposed to release CO₂. This suggests that titania plays a supporting role in the reaction by forming a carbonate-type intermediate.

Sodium and potassium catalysts are known to be very sensitive to humidity. The hydrothermal stability is poor for the catalyst system presented herein. Studies are being carried out to improve the hydrothermal stability of the catalyst.

Conclusions

In summary, sodium and potassium titanates are synthesized and characterized, and their catalytic performance evaluated by TG/DTG for combustion of diesel soot in air. The experimental results show that potassium and sodium titanates are active for diesel soot combustion and the activity notably enhances with the concentration of K₂O and Na₂O. The BET-surface area and pore volume data show the non-porous properties of the materials. Nevertheless, potassium and sodium titanates have exhibited greater activity than the high surface area hydrated titania, demonstrating the mobility, volatility, enhanced soot-catalyst contact characteristics of the titanates and the ability of the catalysts to release active oxygen species. The results obtained for diesel soot oxidation on potassium and sodium titanates show effective functioning of those catalyst samples which contain titania as a major component.

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