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Oxygen Storage Capacity of Sr$_3$Fe$_2$O$_{7.8}$ Having High Structural Stability

Kosuke Beppu,$^a$ Saburo Hosokawa, $^{ab}$ Kentaro Teramura$^{abc}$ and Tsunehiro Tanaka$^{ab}$

The present study proves that Sr$_3$Fe$_2$O$_{6.75}$ has high performance of oxygen storage capacity as well as high structural stability under severe reduction conditions. The H$_2$ reduction of Sr$_3$Fe$_2$O$_{6.75}$ at 1223 K results in the formation of Sr$_3$Fe$_2$O$_6$, whereas SrFeO$_{2.84}$ easily decomposes to Sr$_3$Fe$_2$O$_6$ and Fe metal by the same treatment. The structural framework of Sr$_3$Fe$_2$O$_{6.75}$ is identical with that of Sr$_3$Fe$_2$O$_6$ bearing the space group of I4/mmm. In the crystal structure of Sr$_3$Fe$_2$O$_{6.75}$, three oxygen sites (8g, 4e and 2a) exist. Among those, only oxygen ions in 2a site are eliminated by the H$_2$ reduction. The result unequivocally indicates that Sr$_3$Fe$_2$O$_{6.75}$ is topotactically reduced to Sr$_3$Fe$_2$O$_6$. The reversible redox cycles between Sr$_3$Fe$_2$O$_{6.75}$ and Sr$_3$Fe$_2$O$_6$ take place at higher temperature above 773 K. The observation correlates with the topotactic oxygen intake/release ability between Sr$_3$Fe$_2$O$_{6.75}$ and Sr$_3$Fe$_2$O$_6$. The oxygen storage capacity of Sr$_3$Fe$_2$O$_{6.75}$ and its response rate are higher than those of the conventional Pt/Co$_2$Zr$_2$O$_6$ even in the absence of Pt loading. Thus, Sr$_3$Fe$_2$O$_{7.8}$ must be of great promise as novel oxygen storage materials.

**Introduction**

Transition metal oxides bearing perovskite structure have received much attention, because of their usefulness as the advanced materials such as catalysts, electronic and/or magnetic devices, and oxygen storage materials (OSMs).3,4 In such application, the characteristic of OSM is in the ability for controlling oxygen partial pressure in gas phase. This ability is not only utilized as the function of oxygen separator or oxygen sensor,5,6 but also serves as the environmental-related material for purifying pollutant gases emitted from automobiles.7,8 The automobile exhaust gas contains some pollutant materials such as hydrocarbon (HC), CO and NOx, which are converted into CO$_2$, H$_2$O by the automobile three-way catalysts (TWCs).9-13 The purification efficiency depends on air-to-fuel ratio (A/F), and all pollutant materials are usually purified in a stoichiometric condition of around A/F = 14.7. In low A/F ratios, HC and CO cannot be completely oxidized, whereas in stoichiometric condition of around A/F = 14.7. In low A/F ratios, HC and CO cannot be completely oxidized, whereas in high A/F ratios the reduction of NO to N$_2$ becomes difficult. Needless to say, the adjustment of A/F at the surface of TWCs is responsible for the ability of OSMs.

In the process of purifying automotive exhaust pollutants, the OSM set at a high temperature around 1273 K,11 and at low A/F conditions (A/F < 14.7) it is further exposed under a reduction condition. A high structural stability under a severe condition is thus undoubtedly one of important functions as OSMs. Various perovskite-related materials or oxysurfide such as BaYMn$_2$O$_{7-δ}$16,17 or Pr$_2$O$_2$SO$_4$18-20 have been recently reported to exhibit high performance as OSM.3,21,22 However, much concern have not paid toward their structural stability under severe conditions. If a structural collapse such as phase segregation or decomposition of these compounds is induced by severe conditions, the performance as OSM must be drastically decreased. Accordingly, it is highly required to search and prepare new OSMs having higher structural stability under severe conditions.

CeO$_2$-ZrO$_2$ solid solution is widely used as one of fundamental components in TWCs. Note that the structural framework in CeO$_2$-ZrO$_2$ is substantially maintained in severe conditions.23 Furthermore, a recent study on the structural and compositional change of pyrochlore-type CeO$_2$-ZrO$_2$ solid solution in the oxidation/reduction process has indicated that the oxidation from Ce$_2$Zr$_2$O$_7$ to Ce$_2$Zr$_2$O$_6$ systematically lowers the symmetry from Fd-3m to P2$_1$3. In this transformation, the original pyrochlore-type cation ordering is maintained without any intermixing between Ce and Zr atoms.24 Such a crystallographic transformation is referred to “topotactic transition” has not been explicitly evaluated as one of important abilities in the field of catalyst design for various catalytic reactions such as NO decomposition or combustion reaction of hydrocarbon.

The topotactic transition has been also known to occur in a specific reduction of Sr-Fe mixed oxides bearing perovskite structure.25 For example, the reduction of Sr$^2+$Fe$^3+$O$_7$ with CaH$_2$ yields Sr$^2+$Fe$^{2+}$O$_5$, the framework of which is analogous...
to that of SrFeO$_3$ having perovskite structure. Although the Sr-Fe mixed oxides are expected to serve as OSMs because of the redox property of iron between Fe$^{2+}$ and Fe$^{3+}$, there has been no report for their properties as OSM. In line with such a context, we have engaged in a systematic investigation for the oxygen storage capacities (OSC) of SrFeO$_{3-x}$ and SrFe$_2$O$_{4-y}$ and their structural stability under severe reduction conditions. Described herein is the first demonstration that Sr$_2$FeO$_3$ has high structural stability in severe reduction conditions, and also high ability as OSM due to topotactic oxygen intake/release. The present observations must be valuable information not only for OSM, but also for the development of new catalyst based on solid state chemistry.

Experimental section

Preparation of Sr-Fe mixed oxides and Ce$_2$Zr$_2$O$_7$ : Citric acid (400 mmol) was dissolved into deionized water (180 mL) at 353 K. Then, strontium carbonate (10 mmol) and iron nitrate nonahydrate (10 mmol for SrFeO$_{3-x}$ and 6.67 mmol for Sr$_2$Fe$_2$O$_{4-y}$) were added and stirred for 2 h to obtain the solution containing metal oxide complexes. Ethylene glycol (400 mmol) was added to this solution, and thus-obtained solution was stirred at 403 K for 4 h to form a gelatinous solution. After the gel was heated in a mantle heater at 623 K for 3 h, the thus-obtained brown powder was calcined at the 1273 K and held at that temperature for 30 min. Ce$_2$Zr$_2$O$_7$ was synthesized by the same method as above, and cerium nitrate and zirconium oxynitrate were used as the starting materials.

Preparation of Pt/Sr$_2$Fe$_2$O$_{4-y}$ and Pt/Ce$_2$Zr$_2$O$_7$ solid solution: Sr$_2$Fe$_2$O$_{4-y}$ or Ce$_2$Zr$_2$O$_7$ was added to an aqueous solution containing a desired amount of Pt(NO$_3$)$_3$(NH$_3$)$_3$, and the slurry was dried on a 80 ºC water bath, followed by calcination in air at 773 K for 5 h. The Pt loading amount was 1 wt% on a metal basis.

H$_2$-TPR and OSC measurements: Temperature programmed reduction (H$_2$-TPR) with hydrogen was carried out with a flow-type reactor. Hydrogen (2 vol % in Ar; 30 ml min$^{-1}$) was passed through the reactor charged with a sample (0.05 g) under atmospheric pressure. The reactor was heated with an electric furnace with a heating rate of 5 K min$^{-1}$ up to 1223 K, and the amount of H$_2$ consommed was monitored with a TC detector of Shimadzu GC8A gas chromatograph. The samples reduced in the equipment with H$_2$-TPR were designated as Sr$_2$Fe$_2$O$_{4-y}$ (red). The abbreviation is followed by reduction temperature. For example, Sr$_2$Fe$_2$O$_{4-y}$ (red-773) refers to the product obtained by the reduction at 773 K of Sr$_2$Fe$_2$O$_{4-y}$.

Oxygen storage capacity measurement (OSC measurement) was carried out with a thermogravimeter (Rigaku ThermoPlus). The samples (0.1 g) were heated to 773 K in Ar and held until the constant weights were achieved. Then, weight changes of the samples upon switching the atmosphere every 20 min between 5% O$_2$/Ar and 5% H$_2$/Ar were recorded isothermally to investigate the oxygen intake/release processes.

Characterizations: The X-ray powder diffraction patterns (Rigaku multiflex or Rigaku UltimaIV) were recorded using CuKα radiation. For Rietveld analysis, the XRD pattern was obtained on another diffractometer, Rigaku multiflex, and analysed by a RIETAN-FP program.

Results and discussion

Fig. 1. XRD patterns of SrFeO$_{3-x}$ (A) and Sr$_2$Fe$_2$O$_{4-y}$ (B). a and c, as-synthesized sample; b and d, the sample reduced at 773 K.

The X-ray powder diffraction (XRD) patterns (Fig. 1; a in (A) and c in (B)) of SrFeO$_{3-x}$ and Sr$_2$Fe$_2$O$_{4-y}$ synthesized by a Pechini method showed that SrFeO$_{3-x}$ had the space group of $I4/mmm$ in the charged ratio of Sr/Fe = 1. The Rietveld analysis (Fig. S1) indicated the existence of an oxygen vacancy site, and the chemical formulation of SrFeO$_{3-x}$ could be determined to be SrFeO$_{2.84}$. When the charged ratio of Sr/Fe was 3/2, phase-pure SrFe$_2$O$_{4-y}$ with layered perovskite structure was formed. The oxygen vacancy of SrFe$_2$O$_{4-y}$ was the same as that of SrFeO$_{3-x}$ (Fig. S2), and the chemical formulation of Sr$_2$Fe$_2$O$_{4-y}$ was determined to be Sr$_2$Fe$_2$O$_{3.75}$. The profiles obtained from temperature programmed reduction of SrFeO$_{3-x}$ and Sr$_2$Fe$_2$O$_{4-y}$ with hydrogen (H$_2$-TPR) are shown in Fig. 2. Two reduction peaks at 750 K and above 850 K were observed in SrFeO$_{3-x}$ but the reduction peak was not clearly observed at above 850 K in Sr$_2$Fe$_2$O$_{4-y}$. The theoretical hydrogen consumption can be calculated by the following equations, in which all of the Fe$^{3+}$...
species are assumed to be reduced to Fe$^{3+}$:
\[ \text{SrFeO}_3 + 1/2 \text{H}_2 \rightarrow \text{SrFeO}_{2.5} + 1/2\text{H}_2\text{O} \quad (1) \]
\[ \text{Sr}_2\text{Fe}_2\text{O}_7 + \text{H}_2 \rightarrow \text{Sr}_2\text{Fe}_2\text{O}_6 + \text{H}_2\text{O} \quad (2) \]

In SrFeO$_{3-x}$ and Sr$_2$Fe$_2$O$_{7-y}$, the amounts of H$_2$ consumed up to 773 K were 852 μmol-O$_2$/g and 618 μmol-O$_2$/g, respectively. These values corresponded to the theoretical values of 900 μmol-O$_2$/g for SrFeO$_{2.84}$ and 704 μmol-O$_2$/g for Sr$_2$Fe$_2$O$_{6.75}$. The results confirmed that all Fe$^{2+}$ species in Sr-Fe mixed oxides were reduced to Fe$^{3+}$ species, as given in the above equations. Actually, the existence of phase-pure Sr$_2$Fe$_2$O$_7$, that is SrFeO$_{2.5}$ in eq (1), was observed from XRD pattern (Fig. 1; b in (A)) of SrFeO$_{3-x}$ (red-773). (as for the abbreviated formulation of such, see the experimental section) The peaks of Sr$_2$Fe$_2$O$_{7-y}$ (red-773) shifted to lower angle than those of Sr$_2$Fe$_2$O$_7$, and the peak intensity decreased by the reduction (Fig. 1; t in (B)). Unfortunately, the structural change in the reduction of Sr$_2$Fe$_2$O$_{7-y}$ up to 773 K could not be determined by XRD patterns. However, the reduction behaviour of this material is shown later by X-ray absorption near edge structure (XANES) spectra for Sr$_2$Fe$_2$O$_{7-y}$.

In the XRD pattern of SrFeO$_{3-x}$ (red-1223) (Fig. 3(A)), Fe metal, Sr$_2$Fe$_2$O$_7$ and SrFeO$_3$ were observed. The reduction peak observed at above 850 K in SrFeO$_{3-x}$ implies that the reduction from Fe$^{2+}$ to Fe$^{3+}$ or Fe metal is occurring. In the case of Sr$_2$Fe$_2$O$_{7-y}$ (red-1223) (Fig. 3(B)), a small amount of Fe metal was formed together with Sr$_2$Fe$_2$O$_7$, but its amount (2 wt%) was much smaller than that (8 wt%) of SrFeO$_{3-x}$ (red-1223). These results indicate that SrFeO$_{3-x}$ easily decomposes to Fe metal or Sr$_2$Fe$_2$O$_7$ by H$_2$ reduction above 850 K. Of importance here is that the crystal structure of SrFeO$_{3-x}$ is substantially sustained even by the H$_2$ reduction up to 1223 K.

The results of Rietveld analyses of Sr$_2$Fe$_2$O$_{7-y}$ and SrFeO$_{3-x}$ (red-1223) are shown in Table 1 and Fig. 4. The structural framework of Sr$_2$Fe$_2$O$_{7-y}$ was identical with that of SrFeO$_3$, and the space group could be determined to be I4/mmm in each sample. The oxygen ions in $8g$ and $4e$ sites were absolutely occupied in Sr$_2$Fe$_2$O$_{7-y}$, and 25% of oxygen vacancy was observed in $2a$ site. It is noted that no oxygen ions in $2a$ site exist in Sr$_2$Fe$_2$O$_{7-y}$ (red-1223). Fe ions in Sr$_2$Fe$_2$O$_{7-y}$ were predominantly present in an octahedral environment. The H$_2$ reduction eliminated oxygen ions in $2a$ site, and the coordination state of Fe ions changed from octahedral environment to pyramidal with pentacoordinated structure. These results prove that the Sr$_2$Fe$_2$O$_{7-y}$ is topotactically reduced to Sr$_2$Fe$_2$O$_7$ by the H$_2$ reduction at 1223 K.

The XANES spectra of Sr K-edge and Fe K-edge for Sr$_2$Fe$_2$O$_{7-y}$ with or without reduction are shown in Figs. 3(C) and (D). The Sr K-edge XANES spectra of Sr$_2$Fe$_2$O$_{7-y}$ (red-773) indicates that the form of the post edge at 16115 eV was altered by the reduction. The Sr K-edge XANES spectrum of Sr$_2$Fe$_2$O$_{7-y}$ (red-773) was similar to that of Sr$_2$Fe$_2$O$_{7-y}$ (red-1223). The feature of Fe K-edge XANES spectra of reduced samples were nearly the same as those of the fresh sample.

**Table 1.** The results of Rietveld analysis of Sr$_2$Fe$_2$O$_{7-y}$ before/after reduction at 1223 K.

<table>
<thead>
<tr>
<th>Site occupancy</th>
<th>Lattice parameter</th>
<th>$R_{wp}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$a=b$ (Å)</td>
<td>$c$ (Å)</td>
</tr>
<tr>
<td>$8g$ $4e$ $2a$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sr$_2$Fe$<em>2$O$</em>{7-y}$</td>
<td>1 1 0.75(1)</td>
<td>3.8655(12)</td>
</tr>
<tr>
<td>Sr$_2$Fe$<em>2$O$</em>{7-y}$ (red-1223)</td>
<td>1 1 0.07(1)</td>
<td>3.8900(2)</td>
</tr>
</tbody>
</table>
However, the adsorption energy around 7115 eV in reduced samples shifted to lower energy, compared with that of the fresh sample. The edge position has been reported to shift to lower energy with the decrease of Fe valence state. Similarly to this observation, the valence state of Fe decreased by the reduction at 773 K or 1223 K. The Rietveld analysis also indicated that SrFe$_2$O$_{7.5}$ was reduced to SrFe$_2$O$_6$ at 1223 K. Considering the results, the energy shift can be ascribed to the reduction from Fe$^{3+}$ to Fe$^{2+}$.

The XANES spectrum of SrFe$_2$O$_{7.5}$ (red-773) at around 7110 eV was slightly different from that of SrFe$_2$O$_6$ (red-1223). In order to understand the difference, XANES linear curve fitting was performed for SrFe$_2$O$_{7.5}$ (red-1223) by using Fe metal and SrFe$_2$O$_{7.5}$ (red-773). A well-simulated spectrum was obtained as shown in Fig. 5. The molar ratios of SrFe$_2$O$_{7.5}$ (red-773) and Fe metal are 90% and 10%, respectively, the values of which also agreed well with the mass fractions of SrFe$_2$O$_6$ and Fe metal derived from Rietveld analysis of SrFe$_2$O$_{7.5}$ (red-1223). These results allow us to conclude that the local structure around Fe ions in SrFe$_2$O$_{7.5}$ (red-773) is similar to that in SrFe$_2$O$_6$. In addition, the XANES technique indicates that the reduction peak around 750 K observed from H$_2$-TPR profile can be ascribed to the reduction from SrFe$_2$O$_{7.5}$ to SrFe$_2$O$_6$.

The OSC profiles of SrFe$_2$O$_{7.5}$ (Fig. 6) showed that the oxygen intake and release behavior took place at 773 K in response to gas switching of O$_2$ flow and H$_2$ flow. In the oxygen intake/release, the range of weight change, namely OSC, was approximately 2.0 wt%. This value agreed well with the amount of oxygen release estimated from H$_2$-TPR measurement in SrFe$_2$O$_{7.5}$ and also from the phase transition between SrFe$_2$O$_{6.75}$ and SrFe$_2$O$_6$. Although OSC per unit weight of α-Fe$_2$O$_3$ itself was higher than that of SrFe$_2$O$_{7.5}$, the response rate of SrFe$_2$O$_{7.5}$ was obviously superior to that of α-Fe$_2$O$_3$ itself or that of physically-mixed sample of SrO and α-Fe$_2$O$_3$ (Sr/Fe molar ratio= 3/2) (Table 2 and Fig. S3). The OSC of SrFe$_2$O$_{7.5}$ and its response rate were substantially maintained even after the measurement in 5th cycle.

The oxygen intake/release reversibly took place at higher temperature above 773 K, while the OSC slightly decreased with increasing in the operating temperature (Fig. S4). The phenomena was not responsible for a phase segregation or decomposition of SrFe$_2$O$_{7.5}$, but rather due to a thermal-desorption of oxygen ions in this oxide, because the weight loss was obviously superior to that of α-Fe$_2$O$_3$, and SrO + α-Fe$_2$O$_3$. The local structure of SrFe$_2$O$_{7.5}$ is similar to that in SrFe$_2$O$_6$ from H$_2$-TPR.

Table 2. Oxygen storage capacities of various samples at 773 K.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rate of oxygen release / storage</th>
<th>Capacity</th>
<th>ΔW%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µmol-O$_2$/g/s</td>
<td>µmol-O$_2$/g/s</td>
<td></td>
</tr>
<tr>
<td>SrO + α-Fe$_2$O$_3$</td>
<td>2.39</td>
<td>5.98</td>
<td>1.9</td>
</tr>
<tr>
<td>Pt/SrFe$<em>2$O$</em>{7.5}$</td>
<td>7.11</td>
<td>6.62</td>
<td>1.8</td>
</tr>
<tr>
<td>Pt/Ce$_3$Zr$_2$O$_7$</td>
<td>3.99</td>
<td>4.38</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Figure 7 shows X-ray absorption fine structure (XAFS) spectra of reduced and reoxidized samples of SrFe$_2$O$_{7.5}$ in the OSC measurement at 773 K. The XANES and extended X-ray absorption fine structure (EXAFS) spectra of the reduced sample were different from those of the fresh sample. The edge position in XANES spectrum of reduced sample shifted to lower energy than that of the fresh sample, suggesting that Fe$^{3+}$ species in SrFe$_2$O$_{7.5}$ was reduced to Fe$^{2+}$ species. The topoatomic oxygen release slightly induced the local structural variations around Fe and Sr ions in SrFe$_2$O$_{7.5}$ (Fig. 4), resulting in a decrease of the OSC.
in the change in the EXAFS oscillation and the FT spectrum. Significantly, these spectra of the reoxidized sample are essentially identical with those of the fresh sample. From these results, it is obvious that the redox between SrFeO$_2$$_{3}$ and Sr$_2$FeO$_3$ occurred reversibly at 773 K.

Figure S5 shows XRD patterns of the samples obtained by the reduction of physically-mixed sample of SrO and α-Fe$_2$O$_3$ at 773 K. The peaks assigned as an unknown product may be due to a compound analogous to Sr-Fe mixed oxide. The change in response rate during the reduction process (Fig. 6) is thought to be responsible for the formation of Sr-Fe mixed oxide induced by the redox treatment. On the other hand, since Fe$_2$O$_3$ (magnetite) was formed by the reduction of α-Fe$_2$O$_3$ itself, the redox between α-Fe$_2$O$_3$ and FeO mainly occurred. The crystal structure of α-Fe$_2$O$_3$ was different from that of Fe$_2$O$_3$.$^{28,29}$ The space group of α-Fe$_2$O$_3$ is R-3c with corundum structure, the framework of which consists of trigonally distorted octahedra FeO$_6$. The space group of FeO$_6$ is Fd-3m with inverse spinel structure having octahedra FeO$_6$ and tetrahedra FeO$_4$. The transformation from α-Fe$_2$O$_3$ to FeO$_6$ was accompanied by elimination of oxygen ions together with rearrangement of Fe ions. In the H$_2$ reduction of SrFeO$_2$$_{3}$, however, only oxygen ions in 2α site were eliminated without rearrangement of Sr and Fe ions (Fig. 4). As mentioned earlier, the response rates for oxygen intake/release of SrFeO$_2$$_{3}$ were much higher than those of α-Fe$_2$O$_3$ itself. Therefore, the topotactic oxygen intake/release ability between phase-pure SrFeO$_2$$_{3}$ and Sr$_2$FeO$_3$ is apparently related to the fast oxygen storage and release.

The effect of Pt loading is also important in the present study, since the reduction behaviour of CeO$_2$-ZrO$_2$ or Pt$_2$O$_3$SO$_4$ has been documented to be significantly improved by Pt or Pd loading.$^{12,18-20}$ Similarly to the observations, TPR profiles of SrFeO$_2$$_{3}$ with or without Pt loading showed that the peak due to the reduction of SrFeO$_2$$_{3}$ to SrFeO$_2$ reversedly shifted to low temperature of around 450 K by Pt loading (Fig. S6). Thus, Pt loading on SrFeO$_2$$_{3}$ must exhibit OSC performance below 500 K.

For comparison, the OSC performance of home-made Pt/Ce$_2$Zr$_2$O$_8$ was evaluated. The Ce$_2$Zr$_2$O$_8$ of home-made sample was comparable to ICSD No. 162778 (Fig. S7), and its OSC was approximately 1.3 wt% (Table 2). This value corresponds to 406 µmol•O•g-cat and well agrees with the reported value of CeO$_2$-ZrO$_2$ solid solution with 1 wt% Pt.$^{12}$ The OSC of SrFeO$_2$$_{3}$ without Pt loading and its oxygen storage rate were much higher than those of the home-made Pt/Ce$_2$Zr$_2$O$_8$. However, the release rate during OSC of SrFeO$_2$$_{3}$ was not affected by Pt loading, but rather the storage rate drastically decreased (Table 2). Namely, SrFeO$_2$$_{3}$ surprisingly exhibited high performance, regardless of the presence or absence of Pt loading. These results provide a fruitful perspective that the use of SrFeO$_2$$_{3}$ for automotive exhaust catalyst could reduce or eliminate the consumption of critical and precious resources such as Pt or Pd.

In comparison with Ce$_2$Zr$_2$O$_8$, the merit of SrFeO$_2$$_{3}$ in OSC is the volume change of unit cell under the redox atmosphere. Ce$_2$Zr$_2$O$_8$ has been reported to be transformed into Ce$_2$Zr$_2$O$_7$ in a reductive atmosphere.$^{24}$ The variation (0.6%) of the unit cell volume between SrFeO$_2$$_{3}$ (301.20 Å$^3$) and Sr$_2$FeO$_3$ (302.98 Å$^3$) was much lower than that (4.1%) between Ce$_2$Zr$_2$O$_8$ (1172.34 Å$^3$) and Ce$_2$Zr$_2$O$_7$ (1222.43 Å$^3$). When the variation of unit cell volume is large, the structural defects such as crack or warp are considered to easily take place under reduct atmosphere. Therefore, the mechanical strength of SrFeO$_2$$_{3}$ may be superior to that of CeO$_2$-ZrO$_2$ solid solution.

### Conclusions

In summary, the present study on the reduction-resistances and OSC of SrFeO$_2$$_{3}$ and Sr$_2$FeO$_3$ provides the following unambiguous facts. (1) The H$_2$ reduction of SrFeO$_2$$_{3}$ at 1223 K results in the formation of SrFeO$_2$$_{3}$ with maintaining its structural framework, whereas SrFeO$_2$$_{3}$ decomposes to SrFeO$_3$ and Fe metal phases. (2) The topotactic oxygen intake/release ability between SrFeO$_2$$_{3}$ and SrFeO$_6$ reversibly occurs at the operating temperature of the wide range from 773 K to 1073 K. (3) The OSC of SrFeO$_2$$_{3}$ and its response rate are higher than those of Pt/Ce$_2$Zr$_2$O$_8$ even in the absence of Pt loading. These facts indicate that SrFeO$_2$$_{3}$ has not only high performance of OSC, but also high structural stability under severe reduction conditions such as extremely high temperature. Therefore, the SrFeO$_2$$_{3}$ must be promising materials as novel OMS. If SrFeO$_2$$_{3}$, which contains Fe and Sr could be utilized in place of CeO$_2$-ZrO$_2$ solid solution, it would be profitable in view of resources, because the order of the Clark number is Fe >> Zr ≈ Sr >> Ce. Finally, we would like to add that the concept of topotactic transition will be regarded as one of criteria for the catalyst design in future.

### Acknowledgements

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### References

A graphical and textual abstract

Sr$_3$Fe$_2$O$_{7-\delta}$ has not only high structural stability in severe reduction condition, but also high oxygen storage capacity due to topotactic oxygen intake/release.