

## Supporting information

1. **Table 1.** The metal elements molar ratio of the Eu –doped  $\text{Ce}_2\text{LaO}_{5.5}$  samples measured by EDS

Composition of Samples	Stoichiometric molar ratio Ce: La: Eu	Measured molar ratio Ce: La: Eu
$\text{Ce}_2\text{LaO}_{5.5}$	2.0: 1.0: 0.0	1.9758: 0.9693: 0.0
$\text{Ce}_{2-x}\text{LaO}_{5.5-x/2} : x\text{Eu}$ ( $x = 0.1$ )	1.9: 1.0: 0.1	1.8828: 1.0113: 0.0878
$\text{Ce}_{2-x}\text{LaO}_{5.5-x/2} : x\text{Eu}$ ( $x = 0.2$ )	1.8: 1.0: 0.2	1.7838: 1.0260: 0.1887
$\text{Ce}_{2-x}\text{LaO}_{5.5-x/2} : x\text{Eu}$ ( $x = 0.3$ )	1.7: 1.0: 0.3	1.7163: 0.9800: 0.2839
$\text{Ce}_{2-x}\text{LaO}_{5.5-x/2} : x\text{Eu}$ ( $x = 0.4$ )	1.6: 1.0: 0.4	1.5987: 0.9759: 0.3843
$\text{Ce}_{2-x}\text{LaO}_{5.5-x/2} : x\text{Eu}$ ( $x = 0.5$ )	1.5: 1.0: 0.5	1.4928: 1.0412: 0.4824
$\text{Ce}_2\text{La}_{1-x}\text{O}_{5.5} : x\text{Eu}$ ( $x = 0.1$ )	2.0: 0.9: 0.1	1.9722: 0.9139: 0.0907
$\text{Ce}_2\text{La}_{1-x}\text{O}_{5.5} : x\text{Eu}$ ( $x = 0.2$ )	2.0: 0.8: 0.2	1.9673: 0.7967: 0.2023
$\text{Ce}_2\text{La}_{1-x}\text{O}_{5.5} : x\text{Eu}$ ( $x = 0.3$ )	2.0: 0.7: 0.3	1.9914: 0.6871: 0.2902
$\text{Ce}_2\text{La}_{1-x}\text{O}_{5.5} : x\text{Eu}$ ( $x = 0.4$ )	2.0: 0.6: 0.4	2.0228: 0.5879: 0.3951
$\text{Ce}_2\text{La}_{1-x}\text{O}_{5.5} : x\text{Eu}$ ( $x = 0.5$ )	2.0: 0.5: 0.5	1.9851: 0.4863: 0.4949

All the Eu –doped  $\text{Ce}_2\text{LaO}_{5.5}$  samples mentioned in Fig. 2 and Fig. 3 were measured by EDS to achieve the molar ratio of metal elements Ce, La and Eu. It is known that the EDS is a semi-quantitative approach to detect the chemical element of the composition. In spite of the existence of some deviations with the stoichiometric ratio, the obtained data can help us to confirm that the as-product is what we want.

2. on the detailed description of  $\text{Ce}_2\text{LaO}_{5.5}$  composite structure.

It is well-known that  $\text{CeO}_2$  crystallizes in the fluorite crystal structure (face-centered cubic unit cell with a  $\text{Fm}\bar{3}\text{m}$  space group), and ceria single cell contains 4  $\text{Ce}^{4+}$  and 8  $\text{O}^{2-}$  ion. The Ce atoms are at the corner of the cube and are coordinated by eight equivalent nearest-neighbor oxygen atoms, while the O atoms are tetrahedrally coordinated by 4 Ce atoms. The schematic diagram of  $\text{CeO}_2$  unit cell can be found in our previous published reference (J. Mater. Chem., 2012, 22, 23461–23467).

Fig. 7 in the manuscript shows the structural diagram of  $\text{Ce}_2\text{LaO}_{5.5}$  consisting of six ceria single cells. There are 16  $\text{Ce}^{4+}$  (green ball), 8  $\text{La}^{3+}$  (blue ball) and 44  $\text{O}^{2-}$  (red ball), in which 1/3 of  $\text{Ce}^{4+}$  are replaced by  $\text{La}^{3+}$  ions. Owing to the charge difference for the Ce and La cations, four oxygen vacancies (yellow ball) are formed to balance the charge difference. Additionally, the structural projected images of  $\text{Ce}_2\text{LaO}_{5.5}$  in different directions are given in the following Fig. 7.1.

Fig. 7.1. The structural projected image of  $\text{Ce}_2\text{LaO}_{5.5}$  composite in different directions

