Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

*Supplementary informatio*n

A method to determine oxygen reduction reaction kinetics via porous dual-phase composites based on electrical conductivity relaxation

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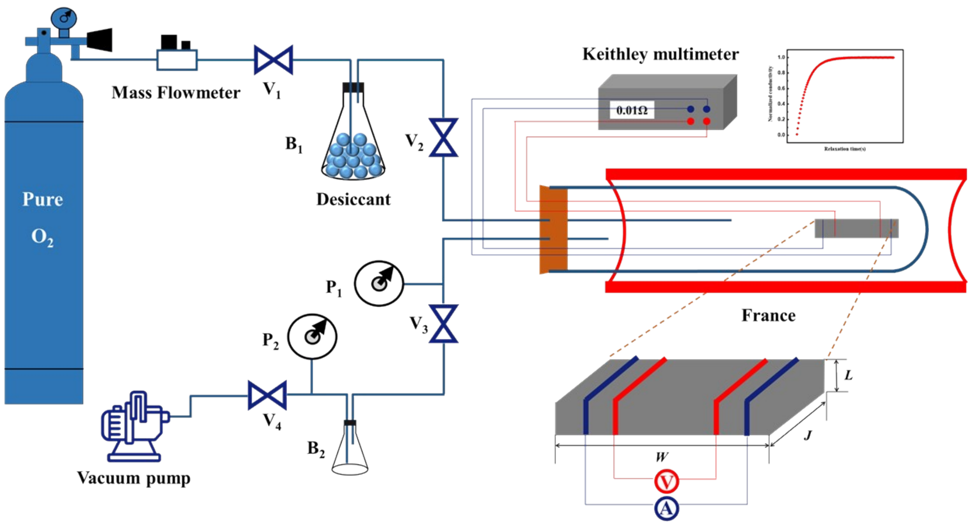

Fig. S1 Schematic diagram for the device designed for the experiment of determining ECR profiles for porous LSCF-SDC composite bar samples. V1-V4 denote valves. B1 and B2 denote buffer bottles. P1 and P2 denote vacuum meters. The unit differs from the actual size. The experimental details are described in our previous work.[1]

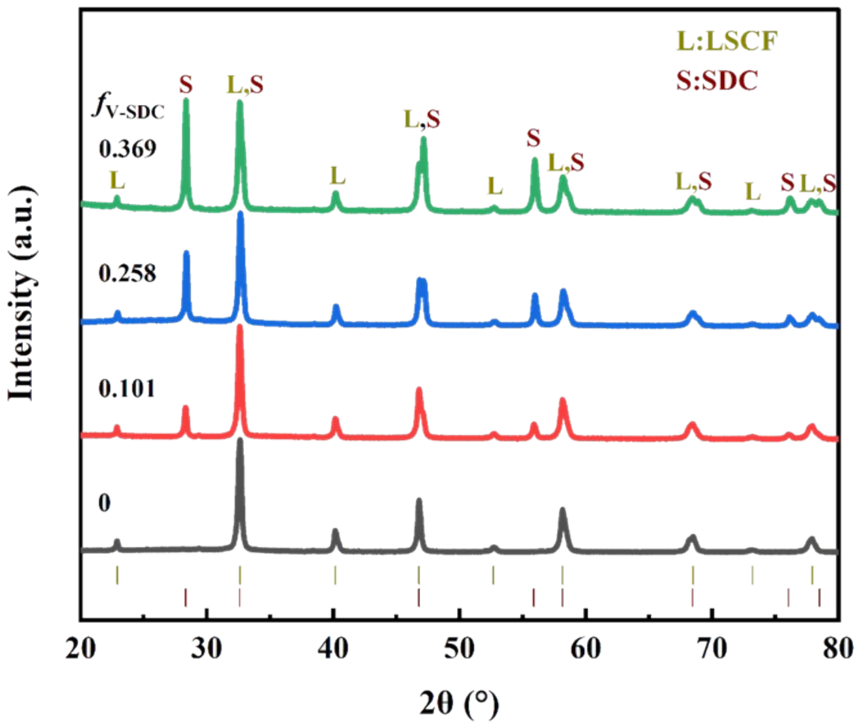

Fig. S2 Room temperature XRD patterns of porous LSCF-SDC composites after sintering at 1000 ℃ for 5 h in ambient air. The SDC volume content in LSCF-SDC is 0 % (pure LSCF), 10.10 %, 25.84 %, and 36.94 %.

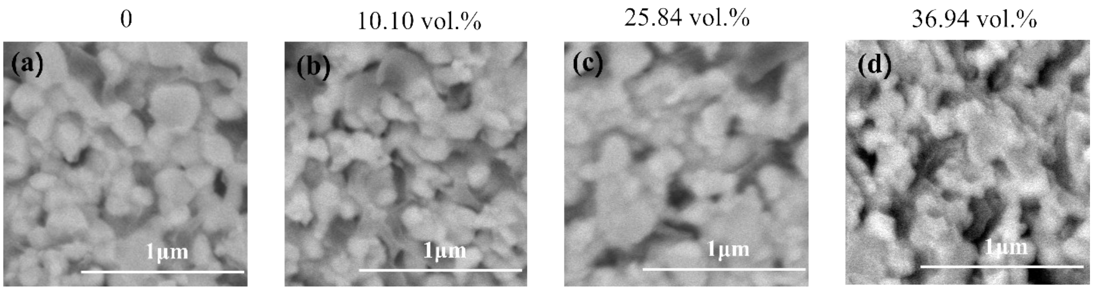

Fig. S3 The BSE images for porous LSCF-SDC composites with various $f_{V\text{-}SDC}$, (a) 0 vol.%; (b) 10.10 vol.%; (c) 25.84 vol.%, and (d) 36.94 vol.%.

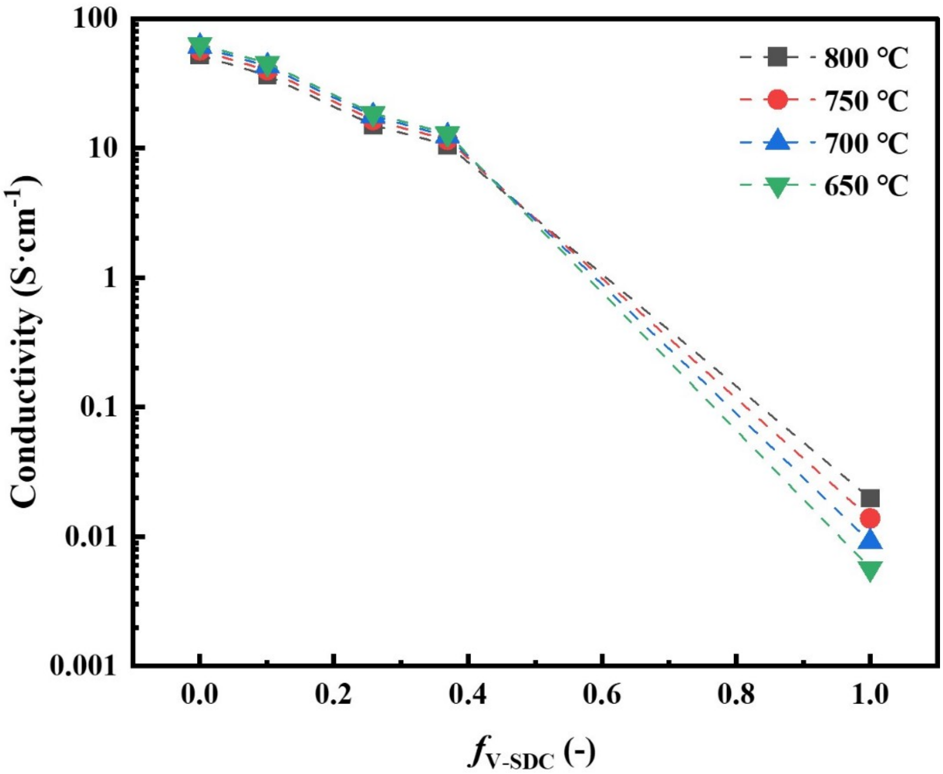

Fig. S4 Conductivity for porous bar samples of bare SDC, bare LSCF, and LSCF-SDC dual-phase composites determine in oxygen at 0.26 atm from 650 to 800 ℃.

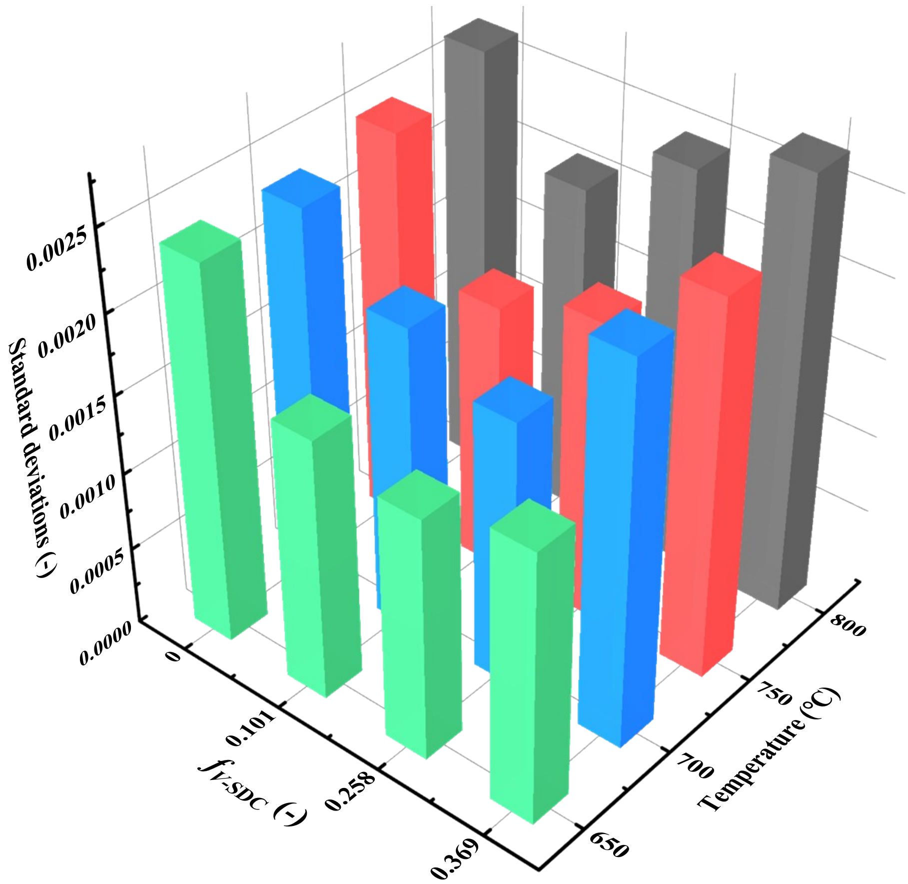

Fig. S5 The standard deviation for DCT fitting of the ECR profiles measured at 650 ℃,700 ℃,750 ℃ and 800 ℃ for porous LSCF-SDC composites with various SDC content.

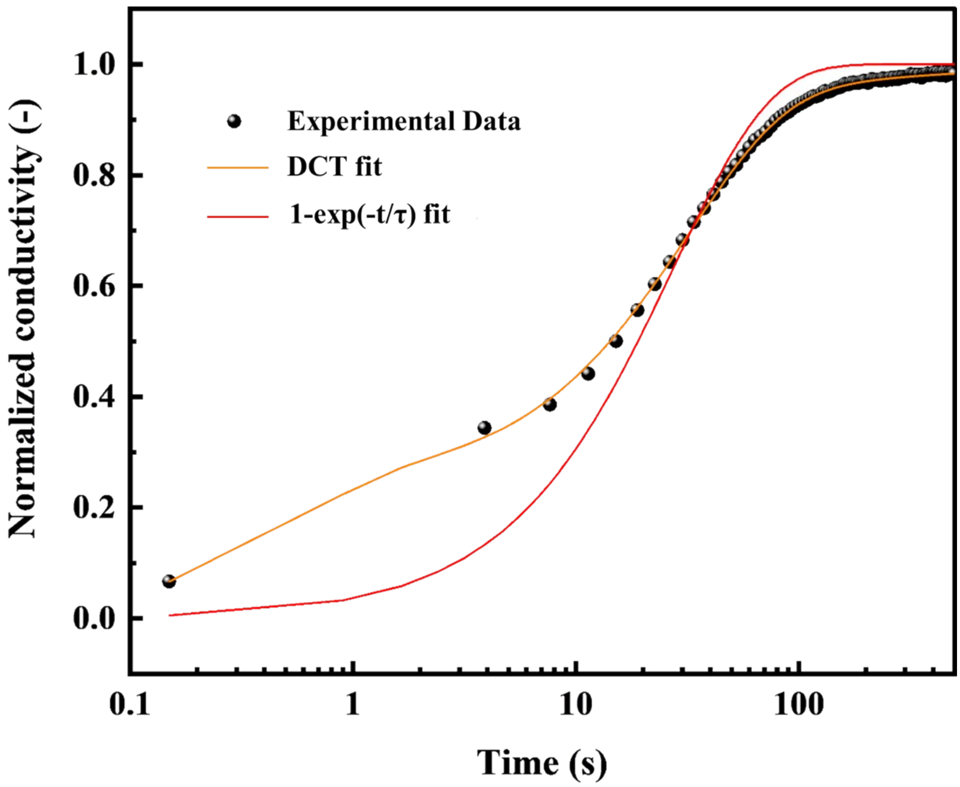

Fig. S6 The comparison between fitting results using the single characteristic time (1-exp(-t/τ)) fitting method and DCT fitting (Equ.11) used in this work. The experimental profile was obtained with porous bare LSCF at 800 °C.[2]

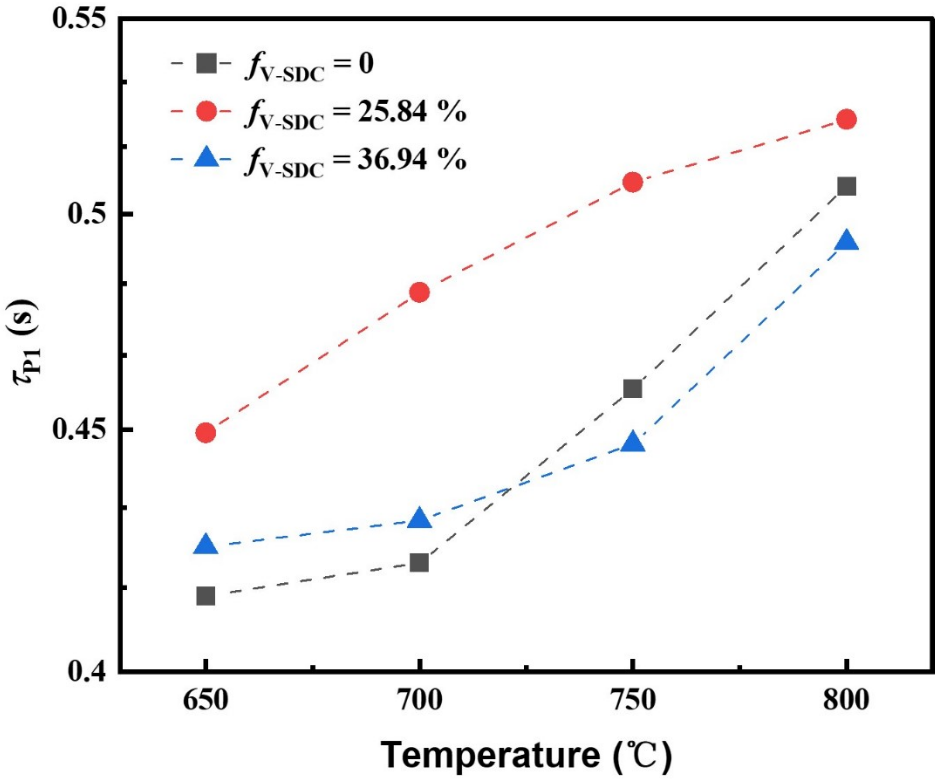

Fig. S7 Testing temperature dependence of the characteristic time of peak 1 (τ_{P1}) with $f_{V\text{-}SDC}$ = 0, 25.84 %, and 36.94 %.

The resistance factor of gas diffusion in large pores, λ_1, is defined as:

$$\lambda_1 = \frac{R_1}{R_1 + R_P} \tag{S1}$$

$$\tau_P = \frac{R_2 * R_3}{R_2 + R_3} = \frac{\tau_2 * \tau_3}{\tau_2 + \tau_3} \tag{S2}$$

$$\tau_3 = \tau_2 + \tau_{3g} \tag{S3}$$

where R is the resistance, τ the characteristic time, 1, 2, 3, and p denote the parameters involved in processes 1, 2, 3, and parallel part, respectively. $R_{3,\,g}$ denotes the resistance of gas diffusion in tiny pores, and its resistance factor is defined as in Equ.S4, λ denotes the total resistance of gas diffusion.

$$\lambda_{3,g} = \frac{\tau_{3g}}{\tau_3} * \frac{\tau_2}{\tau_2 + \tau_3} * (1 - \lambda_1) \tag{S4}$$

$$\lambda = \lambda_1 + \lambda_{3,g} \tag{S5}$$

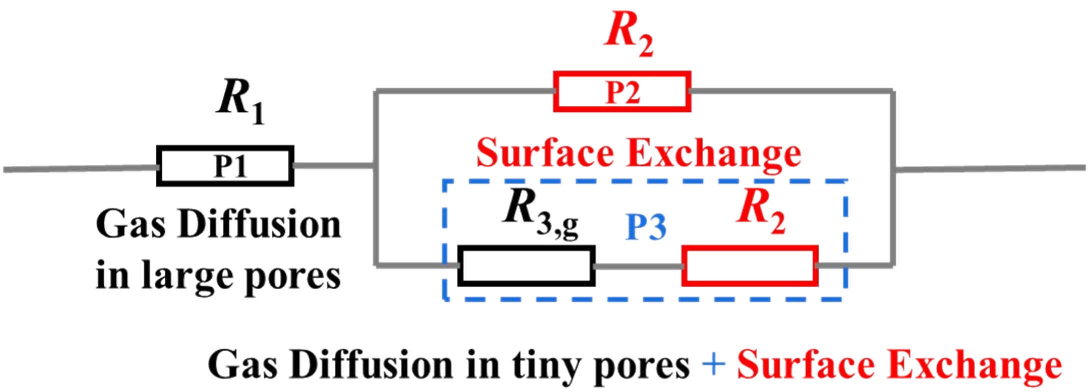

Fig. S8 Schematic diagram showing the routes for ORR in a porous LSCF-SDC composite. One route is the combination of P1 and P2 in series. The other is P1 and P3 in series. Meanwhile, P2 and P3 are in parallel.

Table S1 The parameters involved in Equ.16 at 800 °C.

$f_{V,LSCF}$ (%)	$f_{S,I}$ (%)	A/V (cm^2 cm^{-3})	τ_p (s)	ε (-)
0	1	1.06E+05	24.02	0.518
0.899	0.884	1.12E+05	9.33	0.508
0.7416	0.523	1.01E+05	18.03	0.514
0.6308	0.382	1.09E+05	25.10	0.513

References

1 Y. Zhang, F. Yan, B. Hu, C. Xia and M. Yan, Journal of Materials Chemistry A, 2020, **8**, 17442-17448.

2 R. Ganeshananthan and A. V. Virkar, *Journal of The Electrochemical Society*, 2005, **152**. A1620