101年大學部國際交流甄選專題成果展

Influence of Pressurization on Concentration Polarization for Planar Anode-Supported Solid Oxide Fuel Cells

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Understanding of the influence of pressurization on the anode concentration polarization is important to the cell performance of pressurized solid oxide fuel cells (PSOFC). This motivates the present work to measure AC impedance spectra of an anode-supported PSOFC in a recently-established double-chamber high-pressure testing facility, schematically showed in Ref. [1]. Such testing facility includes three main parts: (1) A single-cell stack that is assembled by an anode-supported PEN with an effective area of 40 × 40 mm^2, crofer 22-APU supporting frames and two current collectors, sandwiched by a pair of rib-channel flow distributors, and embedded in a ceramic housing, (2) a high-temperature program-controlled furnace (the inner chamber) for heating up the inside single-cell stack, and (3) a relatively large outer chamber to provide a high-pressure environment for PSOFC. Figure 1 presents the effect of elevated pressure on the impedance of the aforementioned PSOFC measured at OCV and 800^{o}C conditions with the scanning frequency varying from 0.05 Hz to 3 KHz. We found that the low frequency arcs of impedance spectra with peak frequencies occurring at about 1.5 ~ 2 Hz decrease noticeably with increasing pressure, showing the strong influence of pressurization on polarization resistances. To the other end, the value of high frequency point at real axial of impedance spectra representing ohmic resistances are independent of pressure. By using the equivalent circuit model and the concentration polarization equation to analyze these impedance results, it is found that the concentration overvoltage decreases with increasing pressure. Comparisons with previous experimental and numerical results will be also discussed [2].

Experimental Setup

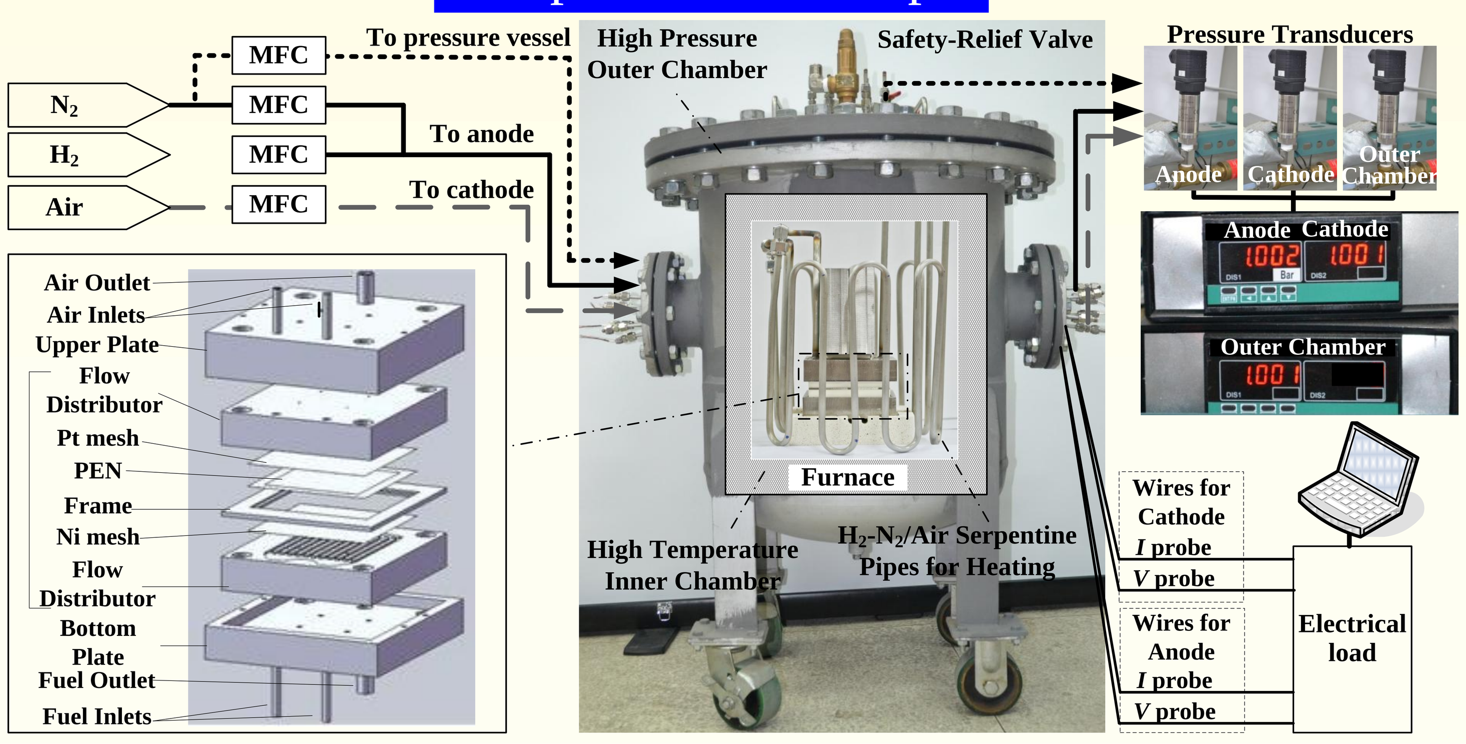
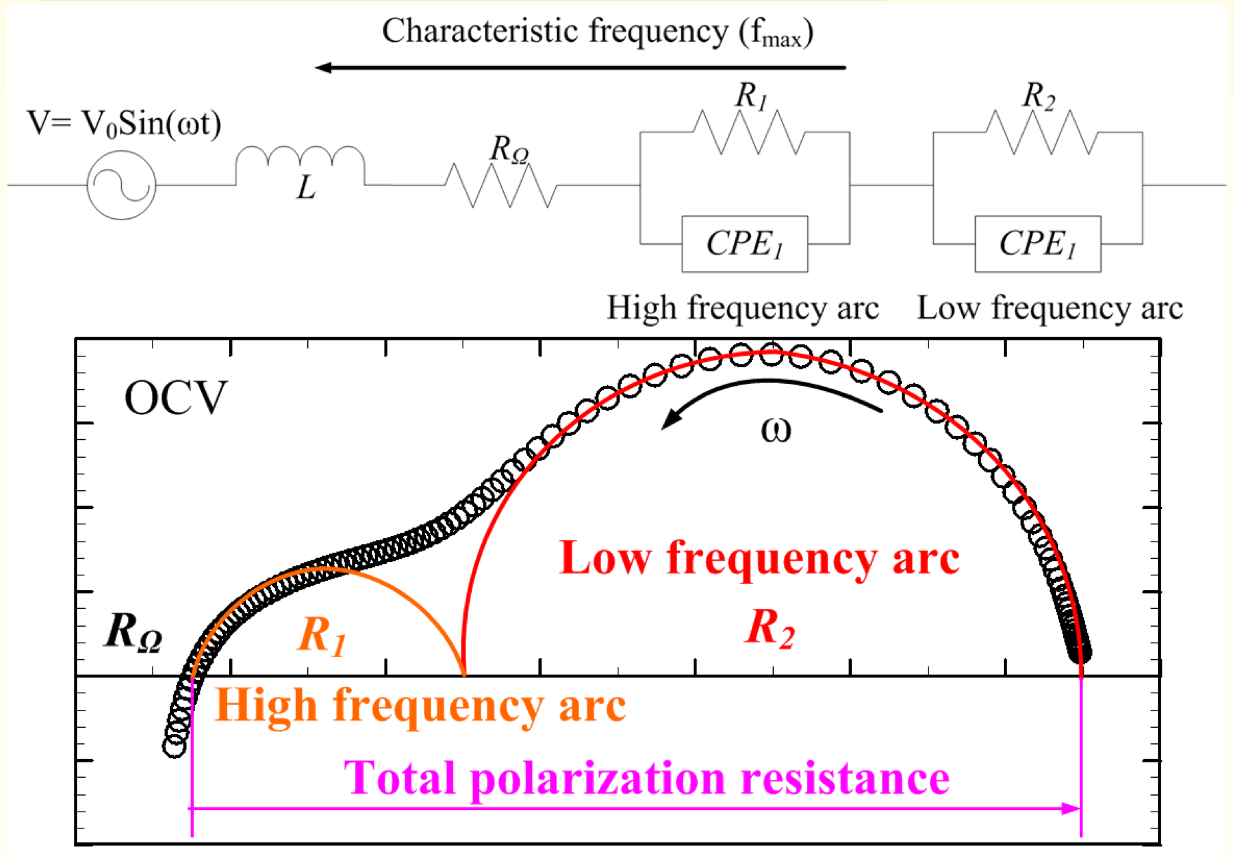


Fig. 1. A high-pressure double-chamber testing platform for cell performance measurements of planar solid oxide fuel cells (center), where a single-cell stack with the heated piping system is assembled inside a programmable furnace (inner chamber) that is resided in a large high pressure outer chamber. Also plotted are an exploding single-cell stack sketch and the measuring facilities [1].

Equivalent Circuit Model (ECM)



ECM Data

800℃ OCV	1atm	2atm	3atm	4atm	5atm
L$_1$(μH)	0.437	0.444	0.418	0.412	0.418
R$_\Omega$(Ω)	0.154	0.154	0.154	0.154	0.154
Q$_1$(F s^{n1-1})	1.38	2.263	2.534	5.267	6.911
n$_1$	0.498	0.475	0.499	0.468	0.461
R$_1$(Ω)	0.037	0.024	0.021	0.017	0.015
Q$_2$(F s^{n2-1})	2.114	3.273	3.978	4.512	7.032
n$_2$	0.982	0.994	0.986	0.988	0.992
R$_2$(Ω)	0.041	0.025	0.022	0.019	0.017
Peak Frequency	1.95	1.95	1.86	1.85	1.3

Low frequency arc

I-V Curve

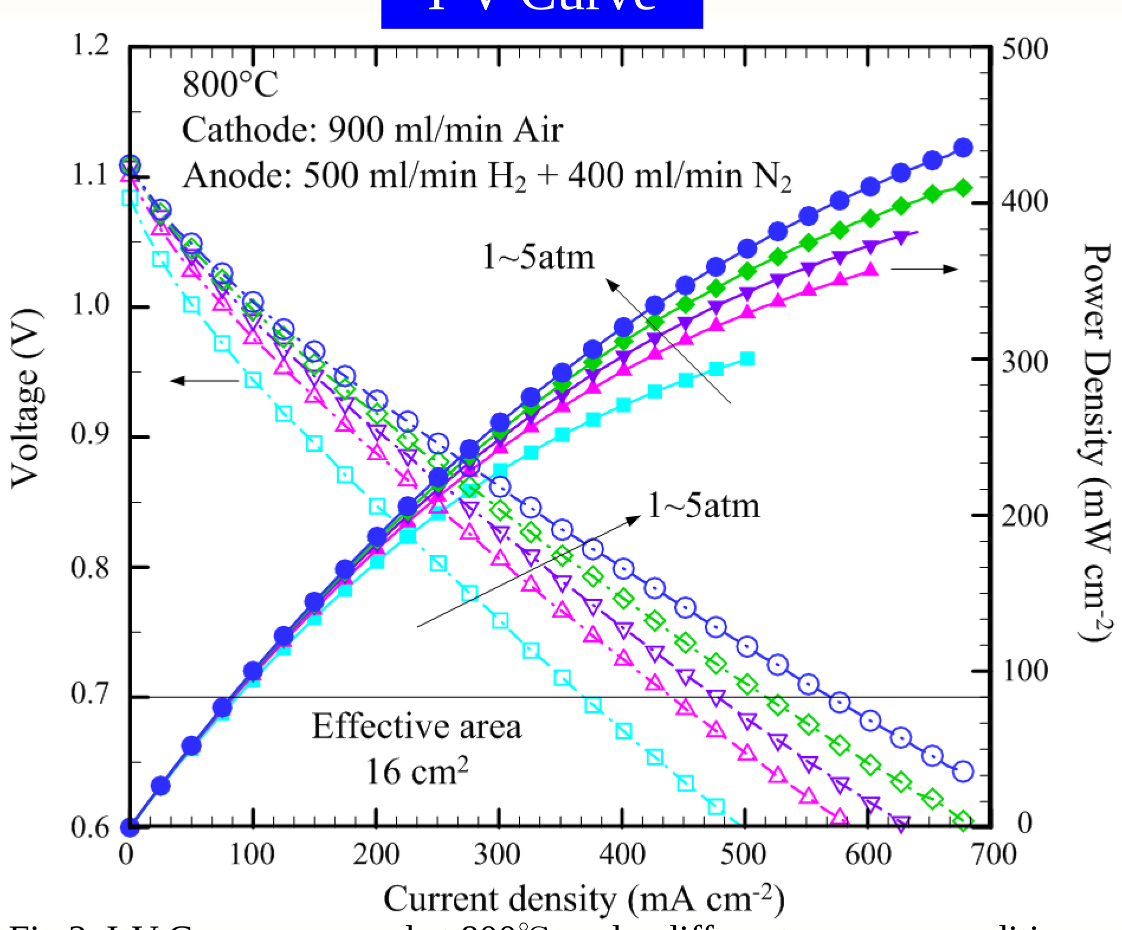


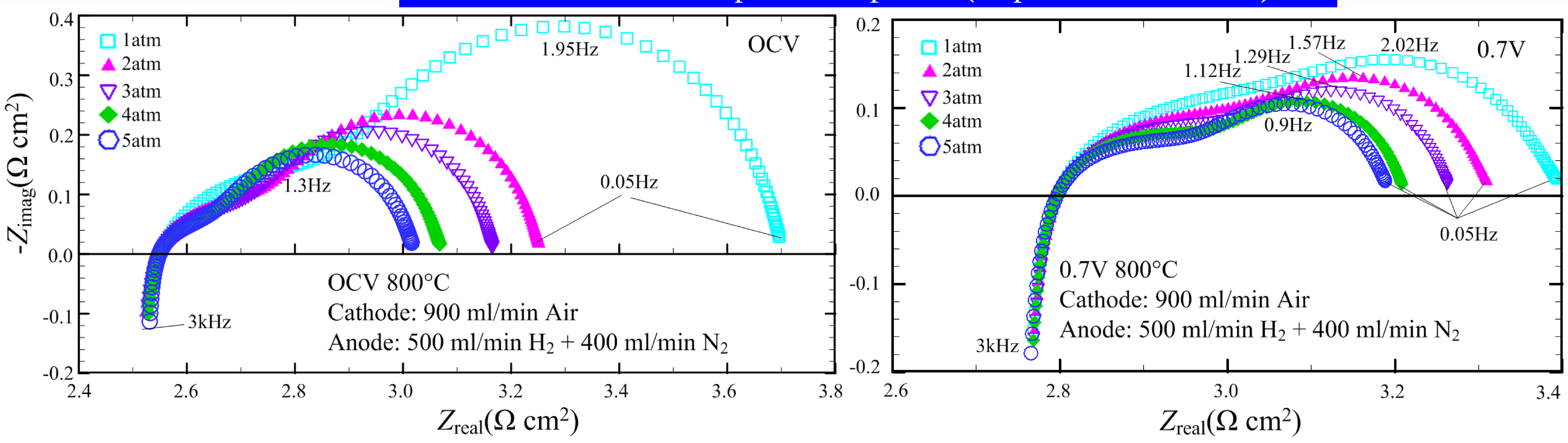
Fig 2. I-V Curve measured at 800℃ under different pressure conditions varying from 0.1MPa to 0.5MPa.

Anode concentration polarization

$$\eta_{concentraton} = \frac{RT}{2F}\ln\left(\frac{1+\left(\frac{RTL}{2FD_{eff}P_{H_2O}}\right)i}{1-\left(\frac{RTL}{2FD_{eff}P_{H_2}}\right)i}\right)$$

$$\frac{d\eta_{concentraton}}{di} = R_2(i\to 0) = \left(\frac{RT}{2F}\right)^2\frac{L}{D_{eff}P}\left(\frac{1}{X_{H_2}}+\frac{1}{X_{H_2O}}\right)$$

Electrochemical impedance spectra (Experimental results)



Open Circuit Voltage

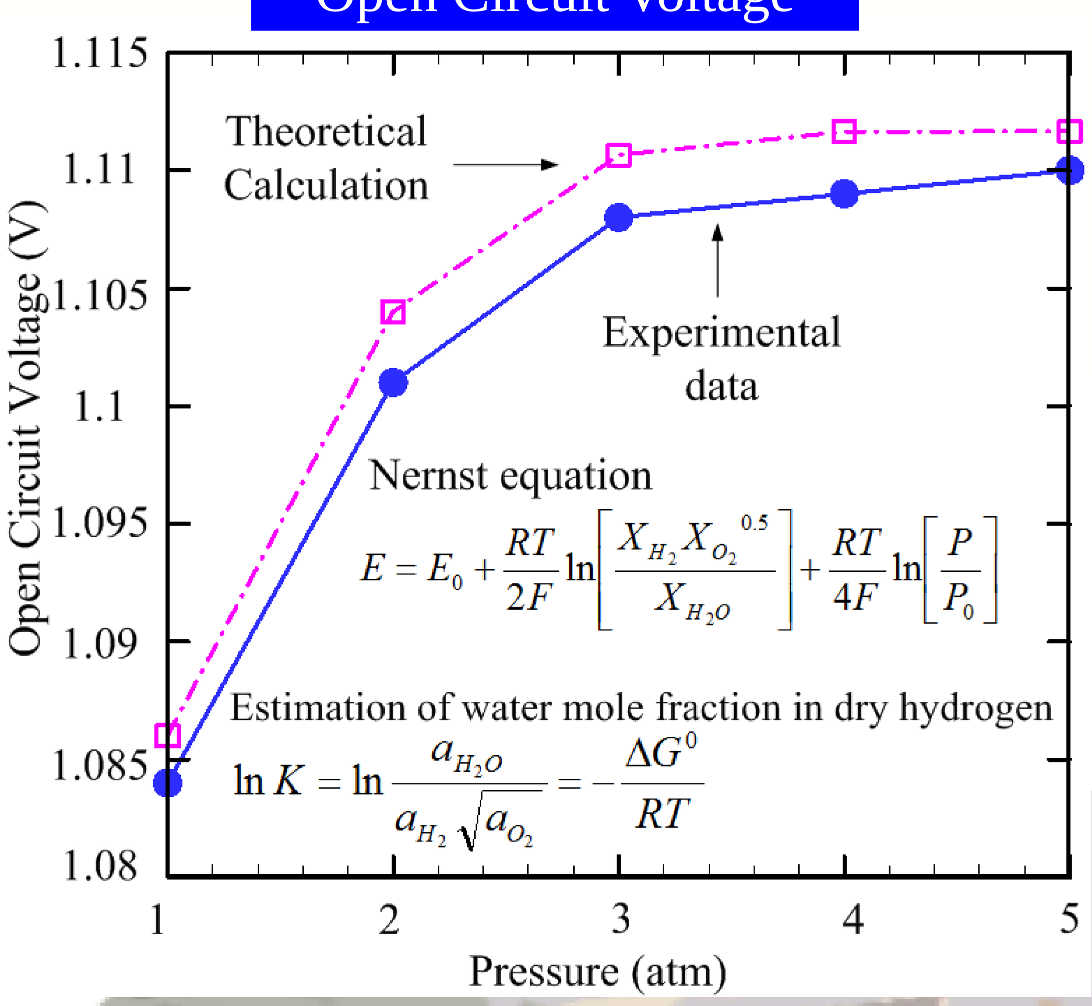
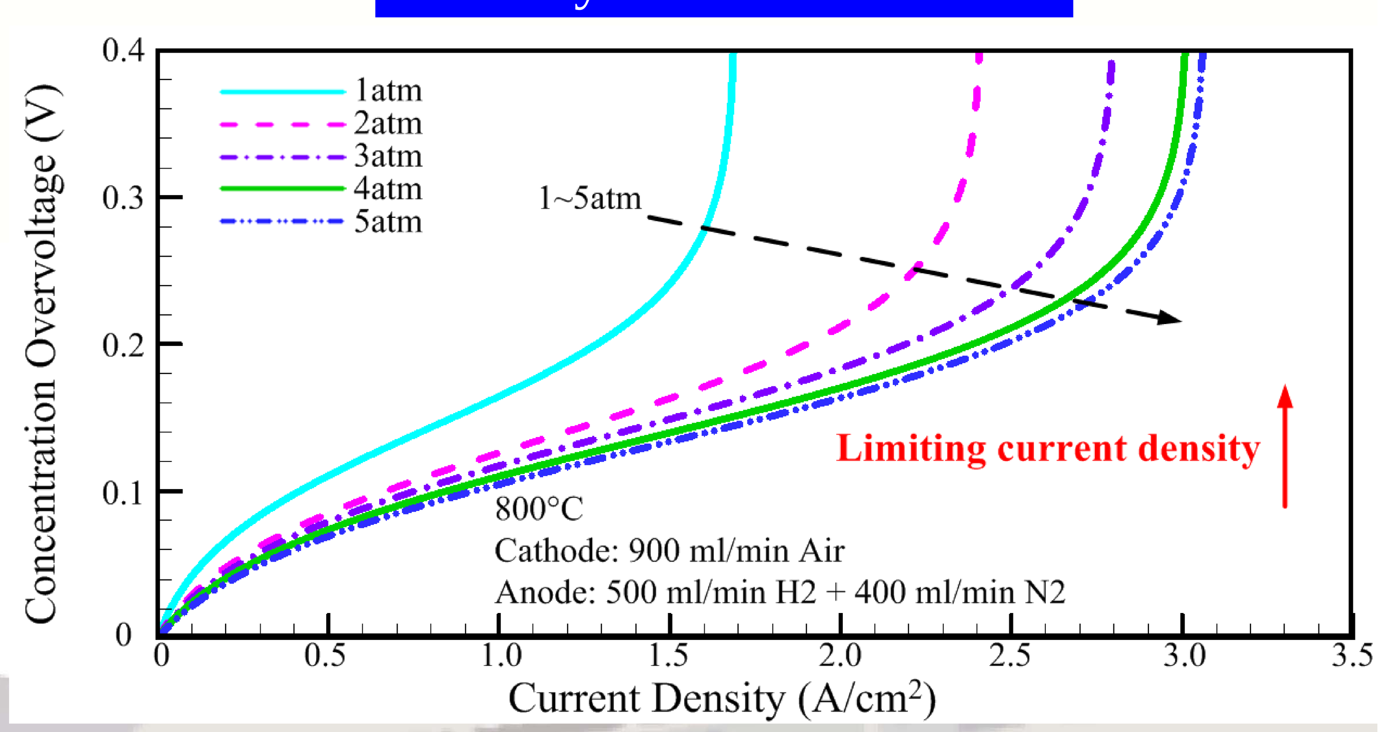
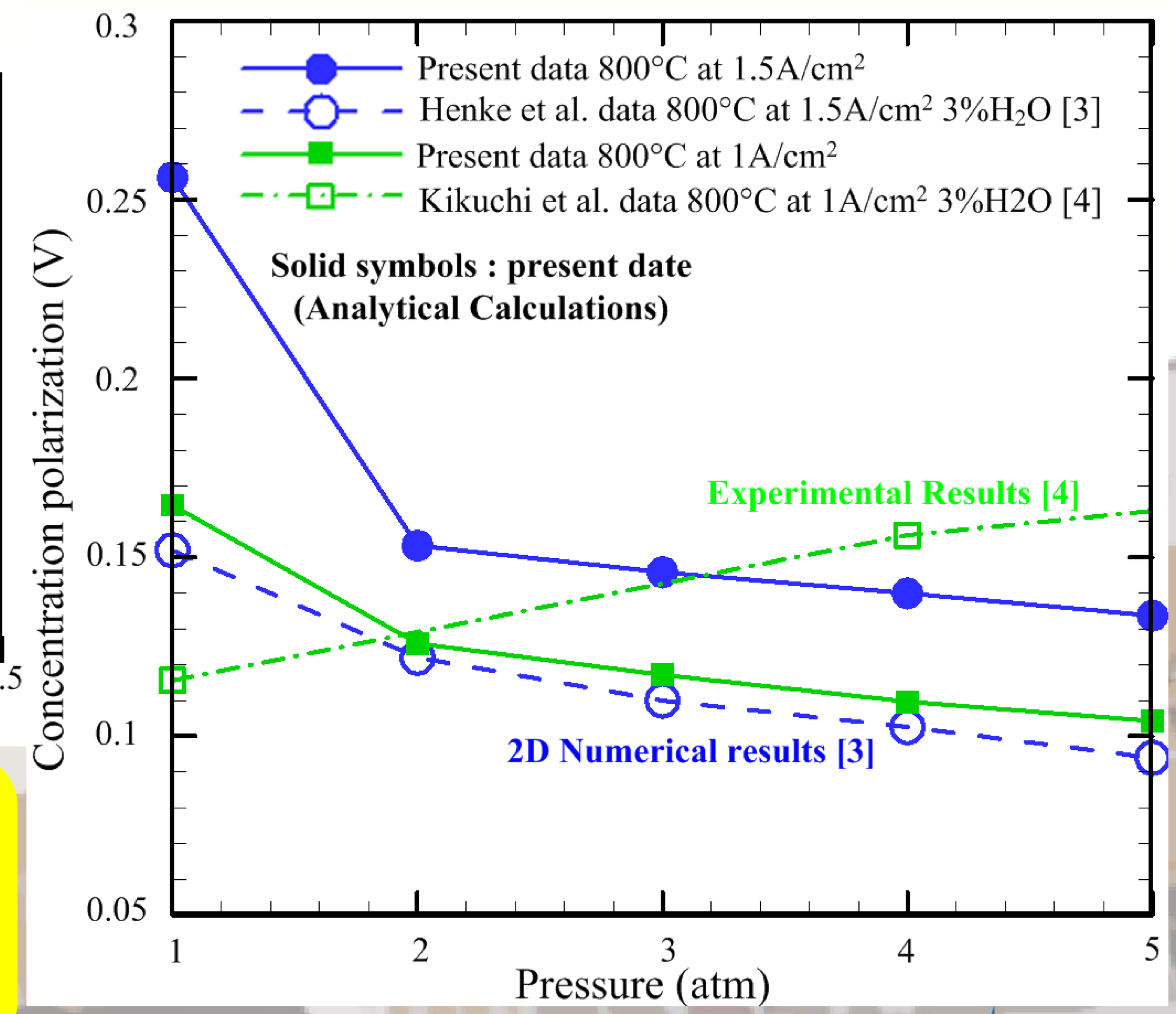


Fig 3.Open circuit voltage measured at 800℃ under different pressure conditions varying from 0.1Mpa to 0.5MPa. The flow rates of air and fuel in cathode and anode, respectively, are the same as Fig 2.

Analytical calculations



The impedance spectra results measured at 800 ℃ under different pressure conditions varying from 0.1MPa to 0.5MPa. Both OCV and 0.7V impedances have been tested. The characteristic frequency and low frequency arc decrease with increasing pressure. The concentration polarization is due to anode mass transport, since the cathode concentration polarization can be neglected when air is used as cathode gas. Analytical calculations are compared with previous experimental and numerical results in the right figure.



[1] Shy SS, Huang CM, Chang HW, Wu PC, "A dual chamber for pressurized planar solid oxide fuel cell performance measurements using different flow distributors", The 2012 Asian SOFC Symposium, September 11-13, Kunshan, China.
[2] Wu PC, Jheng HS, Shy SS, "Influence of pressurization on concentration polarization for planar anode-supported solid oxide fuel cells" , The 2012 Asian SOFC Symposium, September 11-13, Kunshan, China.
[3] Henke M, Kallo J, Friedrich KA, Bessler WG, "Influence of pressurisation on SOFC performance and durability : a theoretical study" , *Fuel Cells 2011* Vol. 11, No. 4, pp.581-591.
[4] Kikuchi R, Yano T, Takeguchi T, Eguchi K, " Characteristics of anodic polarization of solid oxide fuel cells under pressurized conditions" , *Solid State Ionics 2004* Vol. 174, pp.111-117.