

## Development and Performance of Planar SOFC Stacks

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Stacks are made of conventional single cells with configuration of Ni-YSZ/YSZ/LSM-YSZ. Thermal cycling, degradation and power density are investigated. A cell stack unit showed degradation rate of less than 1%/per cycle and maintained 1.15 volt OCV after going through 1350 hours and 46 thermal cycles at 0.1 A/cm<sup>2</sup> and 750°C. The OCV of two-cell stack was above 2.2 V after 400 hours and 15 thermal cycles at 0.1 Acm<sup>-2</sup>. The degradation of two cell stack was also lower than 1% per cycle. A five cell stack has been tested for more than 3000 hours in which the individual stack unit is monitored. Our 10 cell stack reached 310 W with 0.31 W/cm<sup>2</sup> in power density. The single cell could reach 50 W power in the current stack design which corresponds to our results from single cell test with active area of 4×4 cm<sup>2</sup>. A stack of 550 W was built and tested.

### Introduction

For commercialization, it is necessary for planar SOFC stack to have good thermal cycling performance, long life and high power density. Thermal cycling performance is a big concern in stack research which requires thermal expansion coefficient match between stack components, and excellent sealing properties for seals and metallic interconnects (1-4), whereas stack life is determined by the performance of single cells and interconnects. Currently, we have succeeded in fabricating single cells with stable performance and low degradation rate in volume (5-6). Therefore, the performance of interconnects becomes our major concern, such as high oxidation resistance and long-term, stable electrical conductivity at high temperatures at the same time (7). The most popular metallic interconnect today is Crofer 22 APU; however, it is too expensive for commercialization (8). Many Fe-Cr alloys are also used for interconnects (9-10). The requirement of high power density is due to lowering the manufacturing cost and it is critically related to single cell performance, contact resistance of the stack, etc (11). In order to improve power density of the stack, we use soft layer contact between single cells and interconnects to increase contact area between single cells and interconnects and thus reduce contact resistance. This paper is focused on the stack components which have critical influences on the three important features mentioned above and the development of stacks with commercialization prospects.

## Thermal Cycling of Stack

Figures 1 and 2 show thermal cycling performance for stack repeat units and a two-unit stack, respectively. Both stacks were operated at 750°C with a power density of 0.1 Acm<sup>-2</sup>. It can be seen in Fig. 1 that stack repeat unit experienced 46 thermal cycles for a total time of 1350 h whereas each thermal cycle was 120 min. Figure 2 shows thermal cycling performance for the two-cell stack and its components where two different metallic interconnects were used, ferritic stainless steel with and without LSM coating. It shows that the performances of stack components are stable after 6 thermal cycles which may explain the stack's good performance up to 15 cycles. It also shows a degradation rate of less than 1% for a single thermal cycle and the performance of the unit cell without coating is apparently worse than the cell with coating.

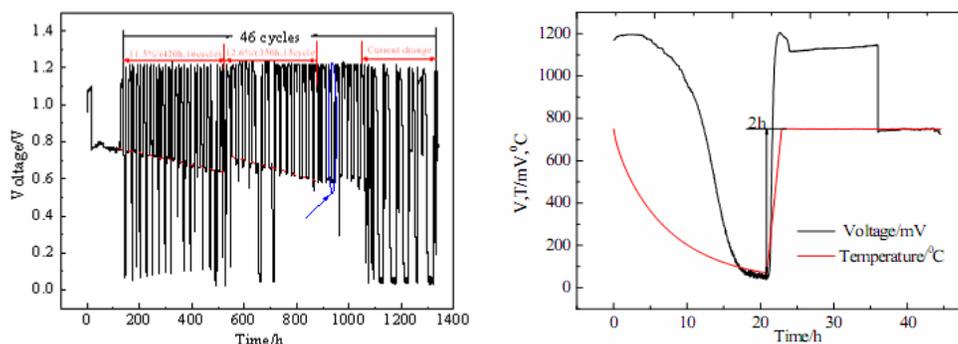


Figure 1. Thermal cycling results of stack repeat unit and start-up time per cycle.

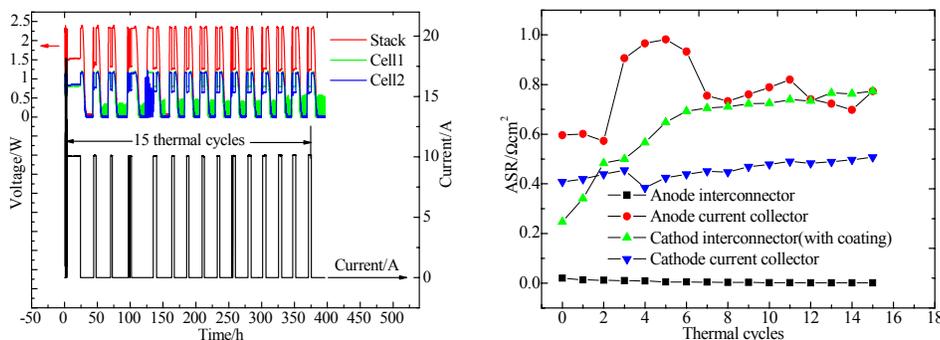


Figure 2. Thermal cycling results of two-cell stack.

## Degradation of Stack

Figure 3 shows the I-V curve of five-cell stack under 0.1 Acm<sup>-2</sup>, 0.2 Acm<sup>-2</sup> operating at 750°C for more than 3000 h. The degradation rate reaches 8.5%/1000 h and 9.62%/1000 h at 0.2 Acm<sup>-2</sup>, 0.1 Acm<sup>-2</sup>, respectively. From Figure 3, it can be seen clearly that the degradation rates of stack repeat units 1, 2, 3, 4, 5 reaches 0%/1000 h, 0%/1000 h, 7%/1000h, 28.4%/1000h, 10.9%/1000 within 1500 h operation under 0.2 Acm<sup>-2</sup>. After 1500 h operation, the degradation rate of stack repeat units 1, 2, 3, 4, 5 reaches 3.6%/1000h, 2.3%/1000h, 2%/1000h, 55.1%/1000h, 5.5%/1000, respectively. It is apparent that the stack repeat unit 4 contributes to most of the degradation of the stack.

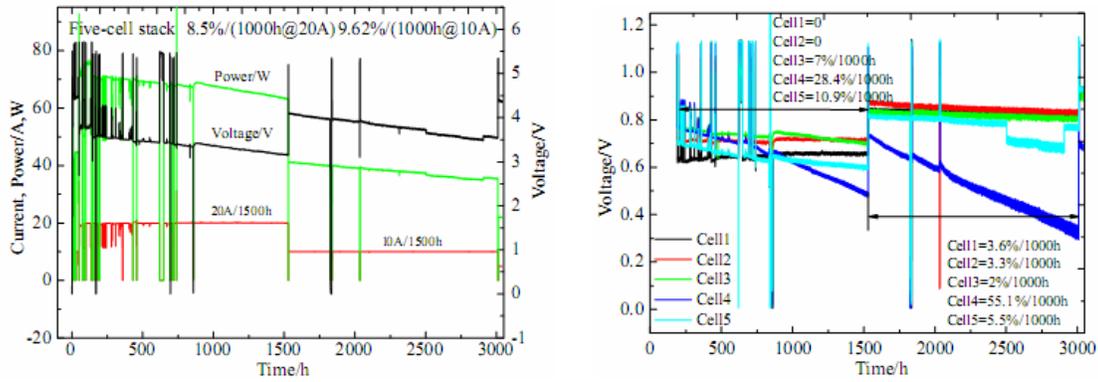


Figure 3. Degradation of five-cell stack and its repeat unit.

### Power Density of Stack

The I-V results for two ten-cell stacks are shown in Fig. 4. The ten-unit stacks achieved maximum powers of 210 and 310 W, respectively, corresponding to power densities of 0.21 and 0.31 Wcm<sup>-2</sup>, respectively. Figure 5 shows I-V curve for a 550 W stack. The stack is built using 34 single cells and has an open circuit voltage of 39.1 V and a power density of 0.16 W/cm<sup>2</sup>. Figure 6 shows I-V results for single cells in ten-unit stacks. Single cells in stack 1 obtained a maximum power of 40 W while cells in stack 2 achieved 50 W, corresponding to power densities of 0.4 and 0.5 W/cm<sup>2</sup>, respectively.

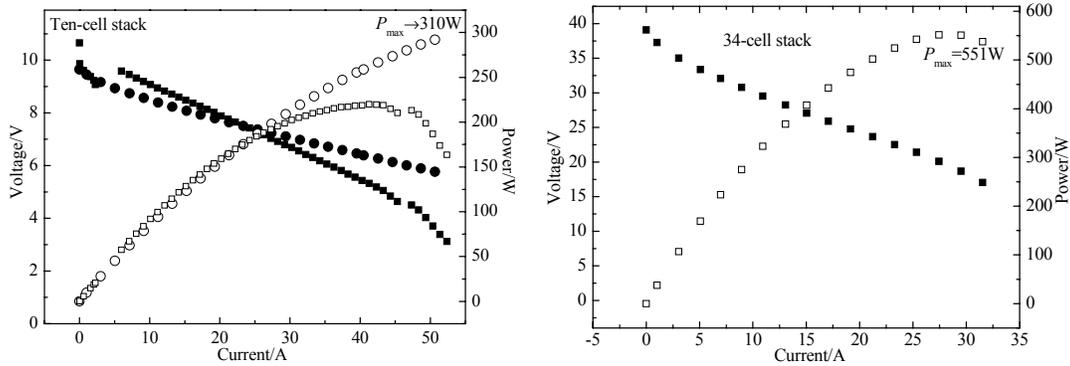


Figure 4. I-V curve of stack at 750°C. Figure 5. I-V curve of 550 W planar stack.

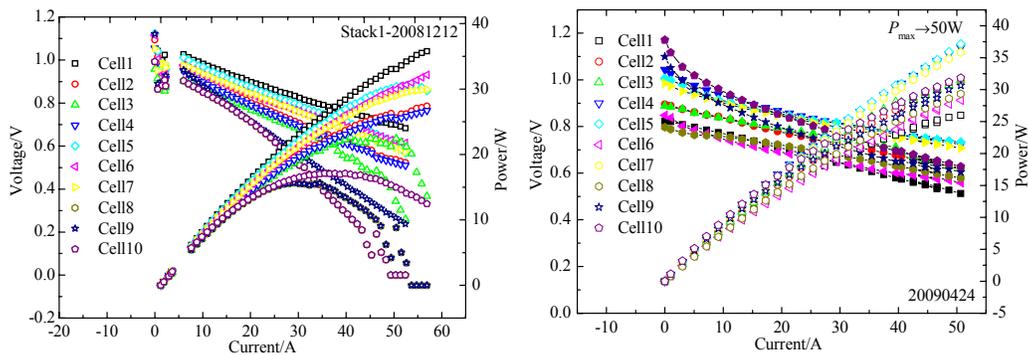


Figure 6. I-V curves of single cells in stack.

## Conclusions

The stack repeat unit and two-cell stacks exhibit stable electrical performance after 46 thermal cycles and 15 thermal cycles, respectively. The degradation of stack after cycling is less than 1% per cycle at 750°C with a current density of 0.1 A/cm<sup>2</sup>. The start-up time per cycle for SOFC stack is not more than 2 hours from room temperature to 750°C.

The degradation of a five-cell stack was not more than 10%/1000 h for 3000 hours at 0.2 A/cm<sup>2</sup> and 0.1 A/cm<sup>2</sup>. Two stack repeat units showed constant voltage without detectable degradation in 3000 h.

The output power of ten-cell stack reaches 310 W with a power density of 0.31 W/cm<sup>2</sup> and the power of single cell reaches 50 W with an active area of 10 cm×10 cm. Currently, the maximum output power of stack is more than 550 W with 0.16 W/cm<sup>2</sup> power density.

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