Degradation and Durability of SOFC Materials by the Impurities

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Introduction and Purpose

●The degradation and durability of SOFC cell-stacks have been a major concern for commercialization. Among many factors associated to degradation of SOFCs, chemical degradation due to impurities is one of the key issues.

● The impurities can react with the component materials and condense at the electrochemical active sites, affecting their properties and reducing the performance of stacks (In Figure 1 left) [1-3]. Such impurities come from gases or diffusion in the solids (fuels, air, and stack components) and they are usually present in very low concentration levels (lower than several tens ppm in weight).

● Secondary Ion Mass Spectrometry (SIMS) technique is being applied to evaluate the concentration levels of impurities in practical stack/modules components under the NEDO project; “Development of system and elemental technology on SOFCs” (2008-2012).

● The purpose of this report are; 1) recent durability and reliability for five different kinds of stacks with detected impurities , and
2) Clarification of degradation mechanism analysis at cathodes and anodes.

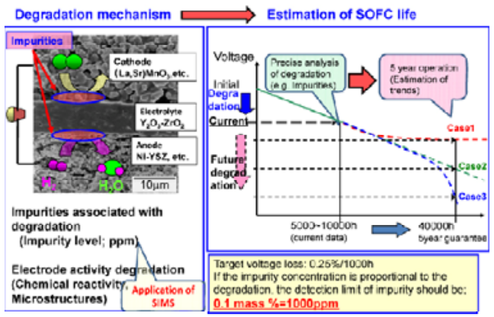

Fig.1 Schematic diagram showing the degradation mechanism and estimation of life time of SOFCs.

Summary

●The effects of impurities on degradation of stacks were examined for 5 different kinds of stacks.

● Very low concentration levels of impurities in the stack components were successfully detected by the SIMS technique.

● The voltage degradation data and impurity related factors were presented; the degradation rates in FY2009 were improved than those of FY2008.

● For impurity affected degradation, some degradation mechanisms were considered associate with chemical reaction of impurities.

Acknowledgements:
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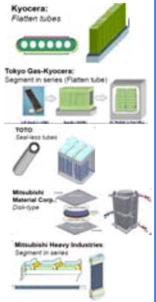
Results and Discussion

Durability of five different stacks

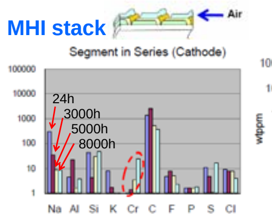
Table 1. Durability of Examined Stacks and Observed Impurities

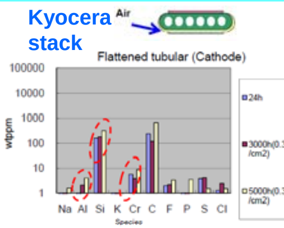
Type	Team (developers)	FY2008; Voltage degradation rate (loss%/1000h)	**FY2009;** Voltage degradation rate (loss%/1000h)	Detected impurities
Flatten tube	AIST-Kyocera	0.9	0.5 (after 2000 h)	Si, Sr, P (interlayer), Corrosion at metallic IC Si (inerconnect)
Segment in series, Flatten Tube	AIST-Tokyo gas	0.42	0.31 (0.24A/cm^2, after 2000h) 0.19 (0.12A/cm^2)	Na, Al, Si, Cr (cathode) F, P, Cl (interlayer)
Tubular	TOTO	1.7	1.1	P, Si (anode/electrolyte) Al, Cr (anode)
Disk	MMC-KEPCO	0.32	0.30	Si, P, S (center of electrodes) Corrosion at metallic IC
Segment in series, Tubular	MHI	0.83	0.73 0.21(5000-5600h, modified stack)	Cr (cathode) Ca diffusion from contact layer

MHI: Mitsubishi Heavy Industries, Japan
MMC: Mitsubishi Materials Corporation, Japan
KEPCO: The Kansai Electric Power Company Inc., Japan



Impurity concentration levels of practical stack components: Application of SIMS technique



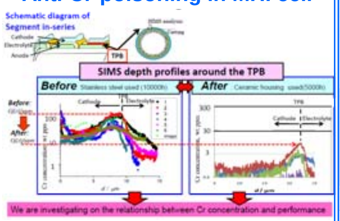


The concentration levels of some elements increase with operation time:
Condensation of impurities with time.
Source of Cr: evaporation of metallic components

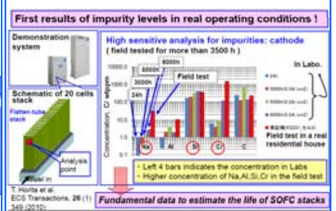
Improvements of cell-stack

Analysis of demonstrative cell- stack

Anti Cr-poisoning in MHI cell

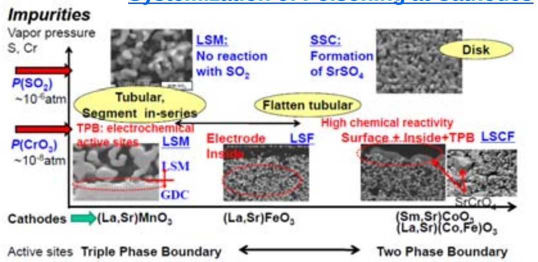


Demonstrative cells



Impurity concentrations and cathode degradations

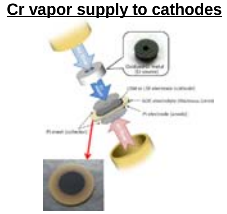
Systemization of Poisoning at Cathodes



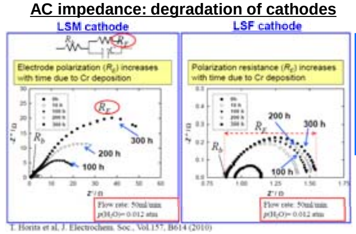
Impurity poisoning at cathodes can be different depending on chemical reactivity and electrode reaction mechanism.

Cr-Poisoning at Cathodes: difference of degradation behaviors and Cr concentration

Cr vapor supply to cathodes

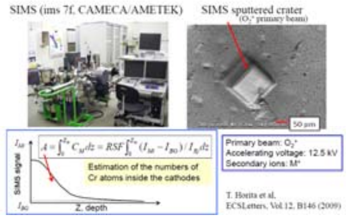


AC impedance: degradation of cathodes

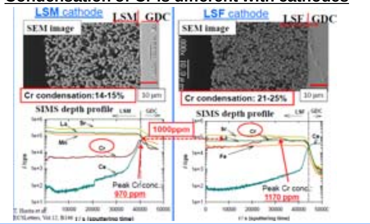


Cr vapors significantly affected the long-term stability of cathodes even in very low vapor pressures: p(Cr)~10^{-8} atm.

Determination of Cr concentration



Condensation of Cr is different with cathodes



S-Poisoning at Cathodes: accelerating degradation by high $p(SO_2)$