Densification and Conductivity on Eight Mole Percentage Yttria Stabilized Zirconia (204NS-G) for Solid Electrolyte Application

by

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LIST OF ABBREVIATIONS

3YSZ	3 mol% Yttria Stabilized Zirconia
5YSZ	5 mol% Yttria Stabilized Zirconia
8YSZ	8 mol% Yttria Stabilized Zirconia
a	Acceleration
AC	Alternative Current
C	Carbon
CaF_2	Fluorite Structure
CaO	Calcium Oxide
Co	Cobalt
CRH	Conventional Ramp and Hold
C-ZrO_2	Cubic Zirconia
D1	Optimum Composition of Fe_2O_3
D2	Optimum Composition of ZnO
D3	Optimum Composition of Mixed Composition (Fe/Zn)
DC	Direct Current
Dy_2O_3	Dysprosium Oxide
EDX	Energy Dispersive X-Ray
EIS	Electrochemical Impedance Spectroscopy
Fe	Iron
Fe_2O_3	Iron Oxide
GB	Grain Boundary
Gd_2O_3	Gadolinium Oxide
GI	Grain Interior
G-8YSZ	Granulated 8 mol% Yttria Stabilized Zirconia
ID	Internal Diameter
MgO	Magnesium Oxide
MnO	Manganese Oxide
MWS	Microwave Sintering
M-ZrO_2	Monoclinic Zirconia
Nd_2O_3	Neodymium Oxide

Ni	Nickel
OH	Hydroxide
P	Pressure
$P_{opt, G}$	Optimum Pressing Load for Granulated 8YSZ
$P_{opt, M}$	Optimum Pressing Load for Milled 8YSZ
PSA	Particle Size Analyser
PVA	Polyvinyl Alcohol
r	Radius
Sc_2O_3	Scandium Oxide
SEM	Scanning Electron Microscope
Sm_2O_3	Samarium Oxide
SOFC	Solid Oxide Fuel Cell
SPS	Spark Plasma Sintering
$SrTiO_3$	Strontium Titanate
TEC	Thermal Expansion Coefficient
Th	Thorium
TMOs	Transition Metal Oxides
$t_{opt, G}$	Optimum Sintering Holding Time for Granulated 8YSZ
$T_{opt, G}$	Optimum Sintering Temperature for Granulated 8YSZ
$t_{opt, M}$	Optimum Sintering Holding Time for Milled 8YSZ
$T_{opt, M}$	Optimum Sintering Temperature for Milled 8YSZ
TSS	Two Stages Sintering
T-ZrO_2	Tetragonal Zirconia
U	Uranium
v	Velocity
WD	Water Displacement
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
Yb_2O_3	Ytterbium Oxide
YSZ	Yttria Stabilized Zirconia
ZnO	Zinc Oxide
ZrO_2	Zirconia

LIST OF SYMBOLS

e	Electron
E	Ideal Equilibrium Potential
E_0	Ideal Standard Potential
Fm/3m	Space Group of Cubic
GPa	Giga Pascal (mathematical unit for load or pressure)
h	Hour
KJ/mol	Kilo Joule Per Mole
MHz	Megahertz (million Hertz) (SI unit for Dielectric Constant)
MPa	Mega Pascal (mathematical unit for load or pressure)
°C	Degree Celcius (SI Unit for Temperature)
P21/c	Space Group of Monoclinic
P42/nmc	Space Group of Tetragonal
$<$	Less than
$>$	More than
W/mK	Watts per Metre Degree Kelvin (SI Unit for Thermal Conductivity)
d_{hkl}	Miller Indices
S	Scale Factor
L_k	Lorentz, Polarization and Multiplicity Factors
ϕ	Reflection Profile Function
P_k	Preferred Orientation Function
A	Absorption Factor
F_k	Structure Factor the K_{th} Bragg Reflection
y_{bi}	Background Intensity at the I_{th} Step

Densifikasi dan Kekonduksian Berasaskan Zirkonia Distabilkan oleh Lapan Mol Peratus Yttria (204NS-G) untuk Aplikasi Elektrolit Pepejal

ABSTRAK

Granulasi serbuk zirkonia distabilkan oleh 8 mol% yttria (8YSZ) yang berkos rendah daripada gred 204NS-G telah dicampurkan dengan dopan tunggal $Zn(NO_3)_2$, $Fe(NO_3)_3$ dan dopan campuran (Fe/Zn) pada kandungan mol% yang berbeza (kurang daripada 3 mol%), telah dikaji secara sistematik. Pada permulaan kajian, kesan terhadap suhu dan masa pembakaran serta beban yang dikenakan untuk memadatkan serbuk granulasi 8YSZ telah disiasat. Semua sampel daripada serbuk granulasi 8YSZ tidak mencapai ketumpatan yang tinggi (>90 %) walaupun sampel telah dibakar pada suhu sehingga 1700 °C, dengan masa rendaman persinteran yang lama (7 jam pada suhu 1550 °C) dan mengunakan penekanan dengan beban yang tinggi (3.5 Ton). Oleh itu, serbuk granulasi 8YSZ awal telah dikisar untuk mengubah ciri permukaannya. Kedua-dua serbuk 8YSZ (serbuk awal dan serbuk yang telah dikisar) telah dipadatkan dan disinter. Kajian terhadap masa rendaman persinteran dan beban penekanan yang berbeza dilakukan dan seterusnya perbandingan dibuat terhadap kedua-dua sampel tersebut. Sampel daripada serbuk 8YSZ yang dikisar telah berjaya menghasilkan sampel yang padat (98.33 %) pada suhu 1550 °C selama 5 jam dengan beban 0.5 Ton, seterusnya menjana kekonduksian yang lebih baik (3.6×10^{-6} S/cm). Bagi meningkatkan lagi kekonduksian dan kepadatan sampel 8YSZ gred ini, serbuk 8YSZ yang dikisar telah ditambahkan dengan 1, 2, dan 3 mol% dopan tunggal (Fe atau Zn). Keputusan menunjukkan bahawa kedua-dua dopan telah berjaya mengurangkan tenaga pengaktifan untuk densifikasi serta meningkatkan penumpatan sampel. Antara sampel berdop tunggal, sampel dengan 2 mol% Zn (YSZ-2Zn) telah memberikan kekonduksian yang lebih baik daripada sampel dengan 2 mol% Fe (YSZ-2Fe) iaitu 6.885×10^{-5} S/cm dan 6.251×10^{-5} S/cm, masing-masing. Walaupun densifikasi untuk sampel YSZ-2Fe (92.09 %) adalah tinggi berbanding dengan YSZ-2Zn (90.49%), tetapi sampel YSZ-2Fe mempunyai kekonduksian yang lebih rendah kerana saiz butiran meningkat selepas persinteran. Tambahan lagi, peratus fasa kubik bagi sampel YSZ-2Fe (49 wt%) adalah tinggi daripada sampel YSZ-2Zn (47.4 wt%), tetapi sampel YSZ-2Fe menyebabkan jumlah kekonduksian yang lebih rendah daripada sampel YSZ-2Zn. Ini disebabkan oleh kehadiran fasa tetragonal dalam sampel YSZ-2Fe mempunyai tetragonality yang lebih tinggi. Oleh itu, ion zink mempunyai keupayaan untuk mengawal pertumbuhan butiran dalam sampel 8YSZ yang menyumbang sebagai faktor penting terhadap kekonduksian. Kajian campuran Fe_2O_3 dan ZnO dalam serbuk 8YSZ menunjukkan bahawa sampel YSZ-1.25Fe0.75Zn (Sampel E), YSZ-1.75Fe 0.25Zn (Sampel G) dan YSZ2.0Fe1.0Zn (Sampel Y) mempunyai fasa kubik-ZrO_2 melebihi 50 wt%, saiz kristal yang rendah (20 nm hingga 25 nm), morfologi bebas liang dengan penumpatan lebih 90 % dan masing-masing mencapai kekonduksian ionik yang lebih tinggi iaitu 2.473×10^{-5} S/cm, 2.578×10^{-5} S/cm dan 7.398×10^{-6} S/cm pada suhu 300 °C. Antara ketiga-tiga sampel, sampel G (YSZ-1.75Fe0.25Zn) didapati sebagai sampel terbaik yang memberikan hasil kekonduksian ionik yang lebih tinggi. Singkatnya,

dopan bercampur (Fe/Zn) menghasilkan seramik yang sangat baik yang boleh menyumbang kepada pembangunan teknologi elektrolit pepejal.