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14. ABSTRACT

Student presentation at 2014 Benedict College Summer Research Institute

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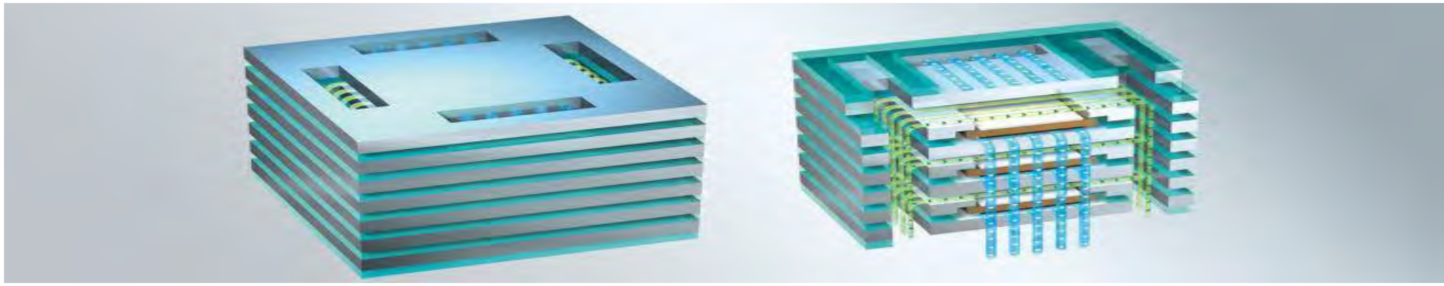
Report Title

Composition Study of LT-SOFC Electrolyte

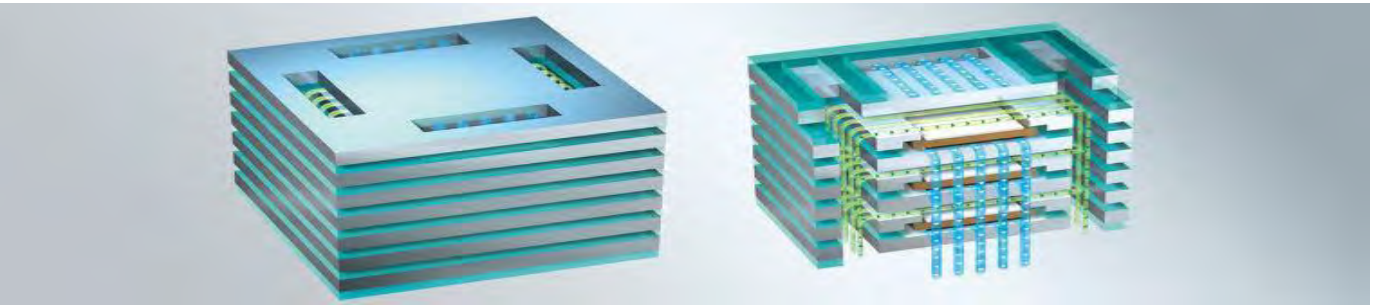
ABSTRACT

Student presentation at 2014 Benedict College Summer Research Institute

SUSAN NJOKI



Compositional Study of a New Low Temperature Solid Oxide Electrolyte $Sr_{1-x}A_xSi_{1-y}B_yO_{3-\delta}$



Dr. Changyong Qin

OUTLINE

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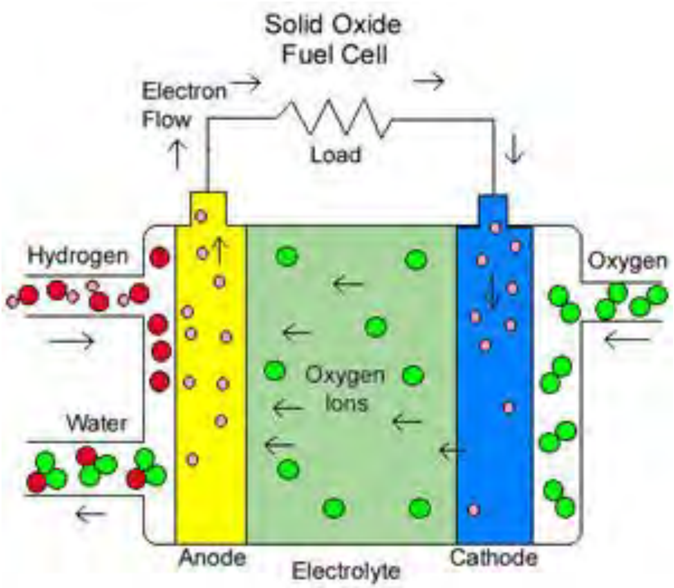
Background

- Solid-oxide electrochemical cell (SOEC) is reversible chemical-electrical energy conversion device
- It uses hard ceramic electrolyte with operation temperature of 800-1000^{0}C
- The high temperature increases production cost and reduces cells durability
- Hence the effort of many researchers is directed towards decreasing the operation temperature of SOEC

overview



❖ SOFC has two operating modes

-As a solid oxide fuel cell(SOFC) to convert fuel to electricity

-As a solid oxide electrolysis cell (SOEC) to utilize electricity to produce value-added chemicals

❖ H_2 is oxidized by O^{2-} transported from cathode through O^{2-} conducting electrolyte

At the cathode oxygen is reduced by electrons to form O^{-2}

MORTIVATION

- Major challenge facing SOCF's is the long-term stability
- Yttrium-stabilized zirconia (YSZ) is the most commonly used electrolyte but it has to operate at T≥750^{o}C
- This operating temperature is too high to be cost competitive with internal combustion engines
- Various progress has been dedicated to developing high-conductivity and thin-film electrolytes, but the operating temperature is still ≥650^{o}C

Other Research

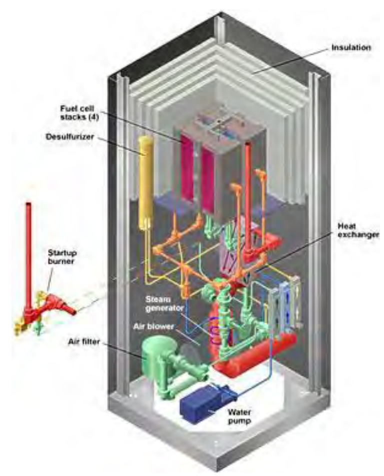
- Exploration of low temperature high performance electrolyte has been shifted towards proton conducting ceramics
- Research conducted in effort to obtain material with best conductivity includes uses of $\mathbf{Sr_{3-3x}A_{3x}Si_{3-3y}Ge_{3y}O_{9-1.5(x+y)}}$ (**A** is either **Na** or **K**) best electrolyte $\mathbf{Sr_{3-3x}NaSi_3O_{9-1.5x}}$ at 500^0C
- Equivalent conductivity to that of the superior solid oxide YSZ at 670^{o}C

Importance

Low manufacturing cost

Combine heat and power generation

Simple configuration



High efficiency and low emissions

Used in sensors

Non CO poisoning

Can be used as back up power units for security

Objective

- Creating a low temperature, compact, fuel flexible solid oxide fuel cell
    - Low in cost
    - Durable
    - High power density
- Thin electrolyte
- Dense electrolyte

Composition

$Sr_{0.8}$ $Na_{0.2}$ Si_{1-y} Al_y $O_{3-\delta}$

$SrCO_3$	$NaCO_3$	SiO_3	AlO_3
$Sr_{0.8}$ 5.9051g	$Na_{0.2}$ 0.5299g	$Si_{0.5}$ 1.5021g	$Al_{0.5}$ 1.2745g
$Sr_{0.8}$ 5.9051g	$Na_{0.2}$ 0.5299g	$Si_{0.6}$ 1.8025g	$Al_{0.4}$ 1.0196g
$Sr_{0.8}$ 5.9051g	$Na_{0.2}$ 0.5299g	$Si_{0.7}$ 2.1026g	$Al_{0.3}$ 0.7647g
$Sr_{0.8}$ 5.9051g	$Na_{0.2}$ 0.5299g	$Si_{0.8}$ 2.4033g	$Al_{0.2}$ 0.5098g
$Sr_{0.8}$ 5.9051g	$Na_{0.2}$ 0.5299g	$Si_{0.9}$ 2.7037	$Al_{0.1}$ 0.2549g

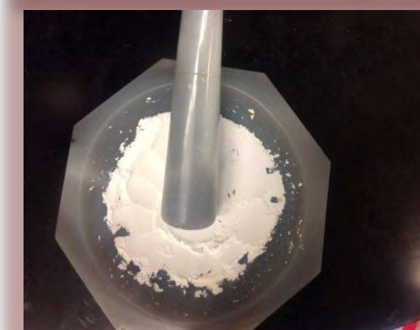
Fabrication

Preliminary step

- Mixing (shaker)
- Grinding (ballmilling)
- Drying (81^0C)

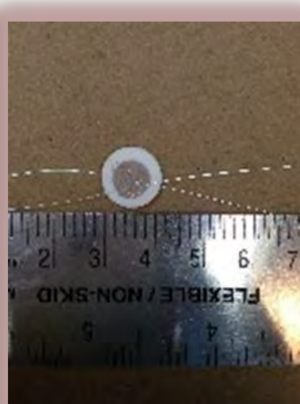
Intermediate step

- Crushing
- pelletizing(200 mpa)
- Calcination(1000^0C) 20hrs



Final step

- Crushing
- Pelletizing(200 mpa)
- Sintering (1150^0C) 20hrs
- sawing



Silver paste used as electrode

Fabrication of Ag doped $SrSiO_3$

	Mixing & Ball Milling	Drying & rushing	pelletiz ing	Calcinatio n 800C 10 Hr	Crushing & Ball milling	Sintering 1200C 10 hrs	sawing
$Sr_{0.9}Ag_{0.1}Si_{3-\delta}$	→	→	→	→	→	→	
$Sr_{0.9}Ag_{0.2}Si_{3-\delta}$	→	→	→	→	→	→	
$Sr_{0.9}Ag_{0.3}Si_{3-\delta}$	→	→	→	→	→	→	→
$Sr_{0.9}Ag_{0.4}Si_{3-\delta}$	→	→	→	→	→	→	
$Sr_{0.9}Ag_{0.5}Si_{3-\delta}$	→	→	→	→	→	→	

Formula for calculation

$R = \rho * L/A$

$\rho = 1/\sigma$

$R = 1/\sigma * L/\pi r^2$

$\sigma = 1/R * L/\pi r^2$

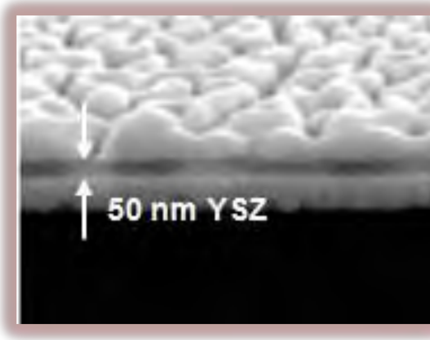
ρ Electrical resistivity

σ conductivity (S/m)

R electrical resistance

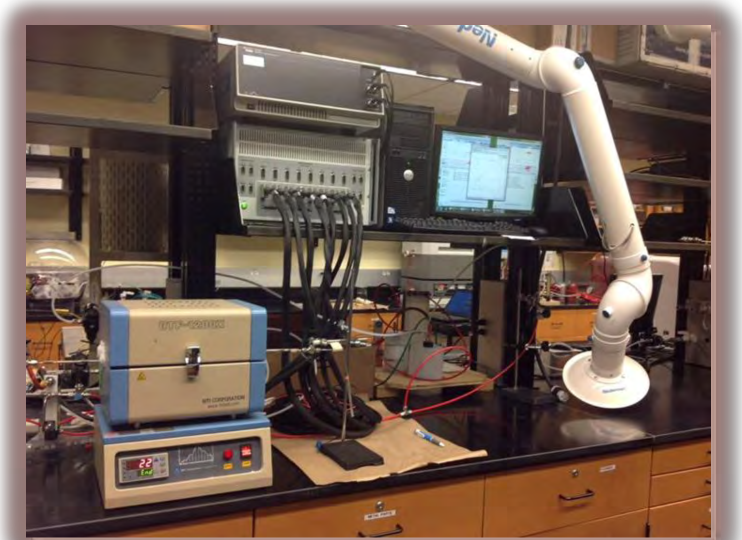
L Length (thickness)

A Area (cross-section)



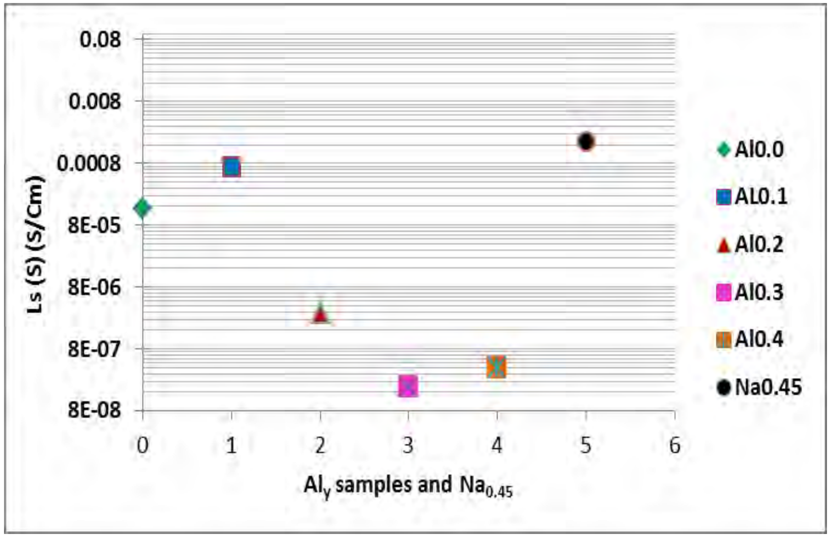
Thin electrolyte
=low Ω

Thick electrolyte
=high Ω



Results

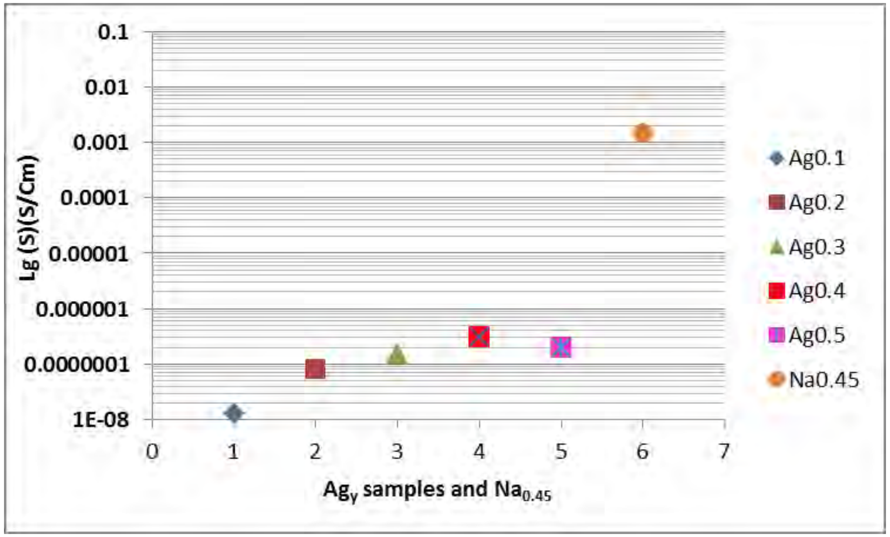
Al Conductivity at 450C



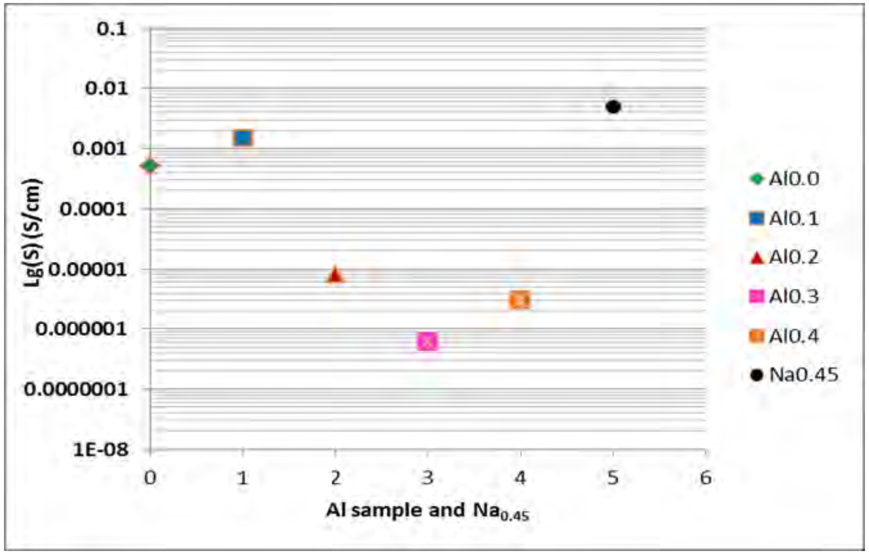
High conductivity observed in $Al_{0.1}$ close to that of baseline $Na_{0.45}$

Ag Conductivity at 450C

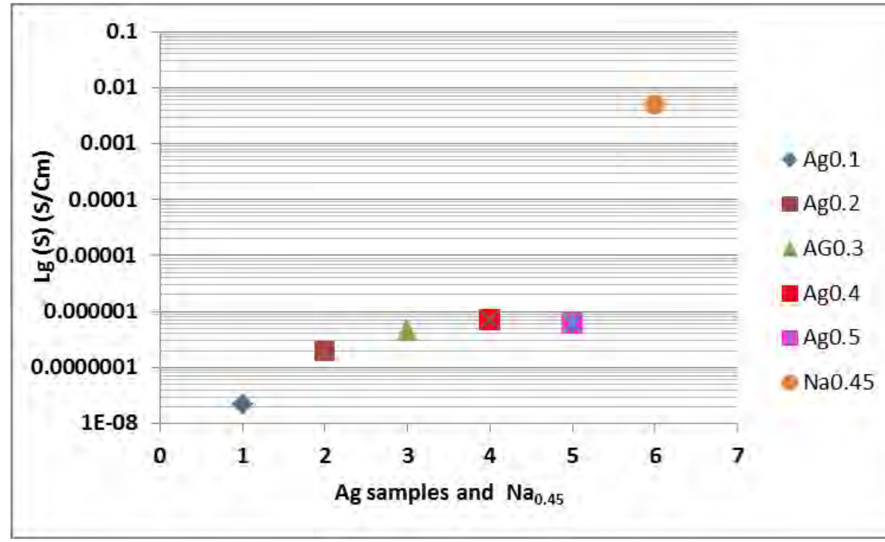
Ag samples has low conductivity



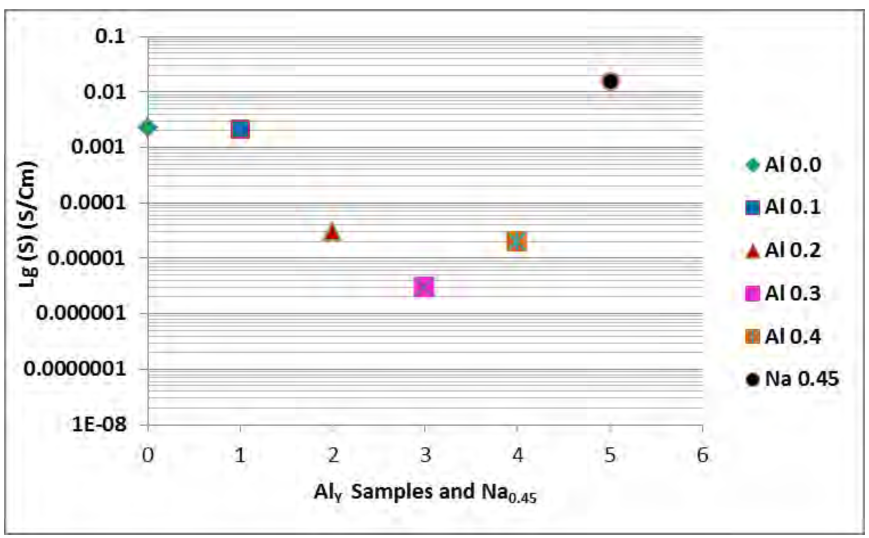
Al conductivity at 500C



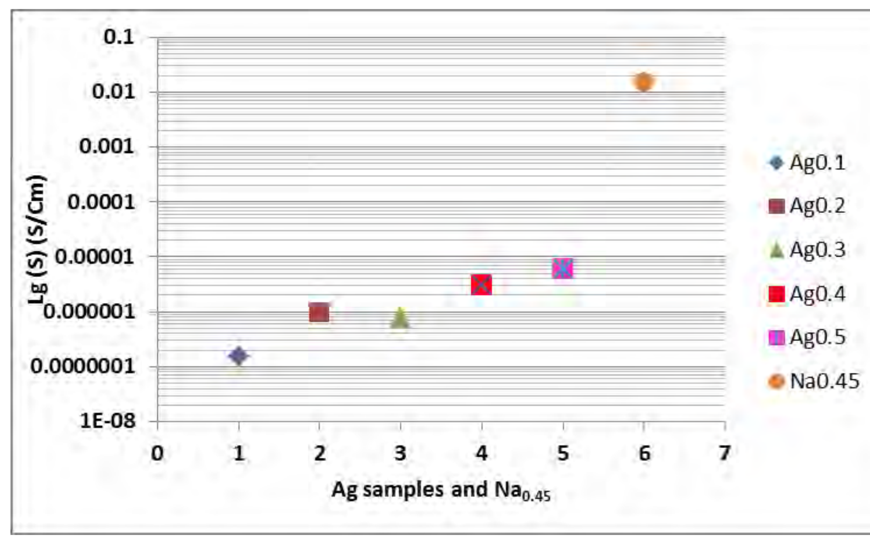
Ag conductivity at 500C



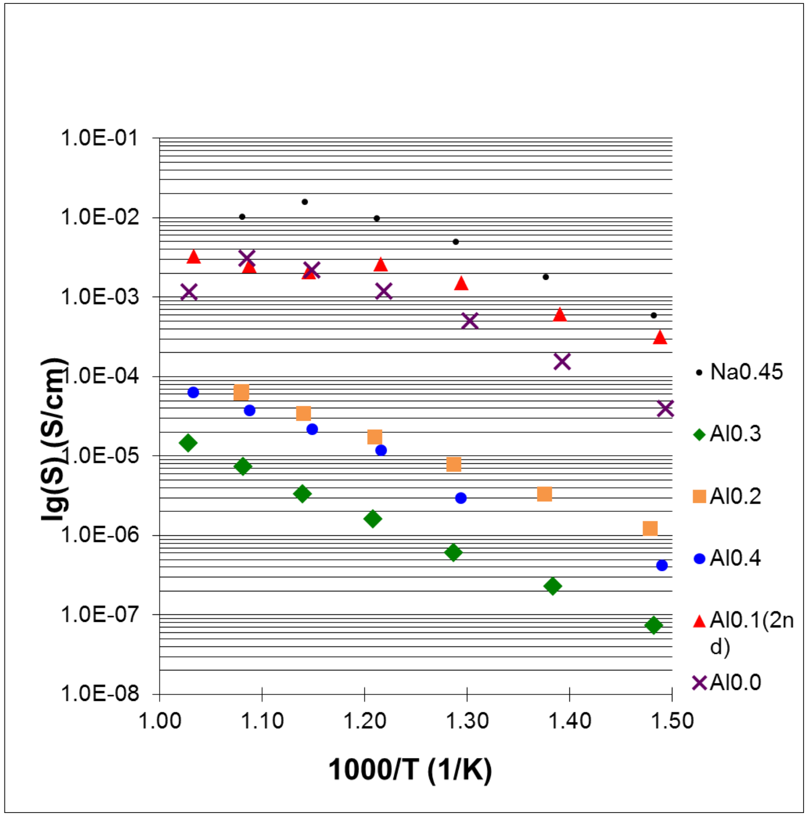
Al conductivity at 600C



Ag conductivity at 600C

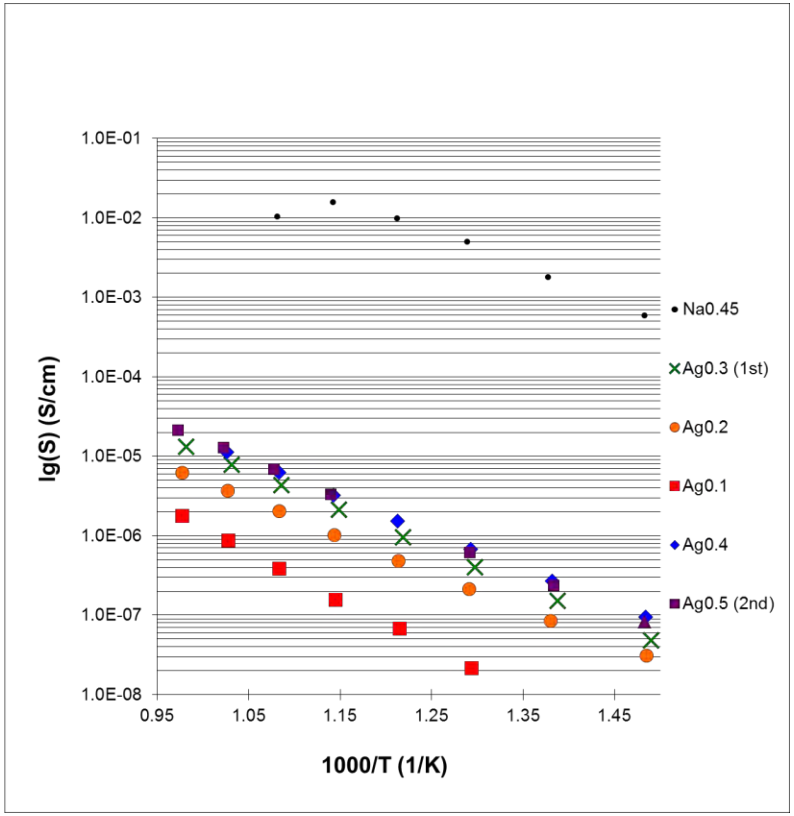


Graphs for Al and Ag samples at different temperature compared to $Na_{0.45}$



Al samples conductivity graph

Ag cells conductivity graph



Conclusion

- Systematically studied the effects of Al and Ag doping on the conductivity of $SrSiO_3$ electrolyte in the temperature range of 400-700^oC
- 10mol% doping of Al was found the best composition leading to the highest ionic conductivity.

Future work

- Fabricate and test conductivity of a combination of

  $Sr_{0.8}Na_{0.2}Si_{0.95}Al_{0.05}O_{3-\delta}$
  $Sr_{0.55}Na_{0.45}Si_{0.95}Al_{0.05}O_{3-\delta}$
  $Sr_{0.55}Na_{0.45}Si_{0.9}Al_{0.1}O_{3-\delta}$

- Investigate microstructure of Al and Ag samples
- Vary the calcination and sintering time of the Al samples
- Vary the calcination and sintering time of the Ag samples
- Doping Al on A site and Ag on B site

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