GLASS AS TEMPLATE FOR NANOSTRUCTURES
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Glass Tutorial Series: prepared for and produced by the
International Material Institute for New Functionality in Glass
An NSF sponsored program – material herein not for sale
Available at www.lehigh.edu/imi
- Evolution of Nanostructure-Phase separation in Glass
- Growth of Nanoparticles at Glass-Crystal Interfaces
- Fractal Growth of Metal in Glasses
- Growth of Nanowires in Glass-Ceramics
- Growth of Core-Shell Nanostructure in Glasses
- Growth of Nano Metal Arrays within a Glass
Two-dimensional continuous random networks. A sketch of a three-fold-coordinated elemental glass is presented.
SCHEMATIC REPRESENTATION OF A SILICATE GLASS
PHASE SEPARATION IN GLASS

Electron micrograph of a glass of Composition 12Na2O, 88SiO2 (mol%) heat-treated at 943 K for ¾ hr.
PHASE SEPARATION IN GLASSES
NUCLEATION AND GROWTH OF PRODUCT PHASE

\[ \Delta F = \frac{4}{3} \pi r^3 \Delta G_v + 4 \pi r^2 \gamma \]

\[ \Delta F^* = -\frac{2 \gamma}{\Delta G_v} \]
NUCLEATION AND GROWTH OF PRODUCT PHASE

\[ \dot{N} \propto \exp\left[-\left(\frac{\Delta F^* + \Delta F_D}{kT}\right)\right] \]

\[ \dot{G} \propto \exp\left(-\frac{\Delta F_D}{kT}\right) \]

\( \dot{N} \) : Nucleation Rate  
\( \dot{G} \) : Growth Rate  
\( \dot{V} \) : Overall Transformation Rate
Growth of Nanocrystalline Metal at Glass-Crystal Interface

Glass $55\text{SiO}_2\ 12\text{ZnO}\ 32.2\ \text{Li}_2\text{O}\ 0.8\text{P}_2\text{O}_5$

Heat treated
$565^\circ C / 1\ \text{hr.} + 630^\circ C / 3\ \text{hr.}$

Glass-Crystal Composites
$\text{Zn}_2\text{SiO}_4 + \text{Li}_4\text{P}_2\text{O}_7 : \text{Crystalline phase}$

Ion Exchange
$\text{Li}^+ \rightleftharpoons \text{Ag}^+ (\text{Silver Nitrate at } 310^\circ C / 8\ \text{hr.})$
$\text{Li}^+ \rightleftharpoons \text{Cu}^+ (\text{CuCl, } 510^\circ C / 3\ \text{hr.})$
$3\text{Li}^+ \rightleftharpoons \text{Fe}^{3+} (\text{FeCl}_3, 300^\circ C / 50\ \text{hr})$

Reducible ion enriched Glass-Crystal Composite Layer

Reduction in H$_2$

Nanoparticles of Metal at Glass-Crystal Interface
Growth of Nanocrystalline Metal at Glass-Crystal Interface
Growth of Nanocrystalline Metal at Glass-Crystal Interface

Size distribution of Silver Particles Synthesized by ion exchange and reduction (873K for ½ hr) in a glass of Composition 55SiO₂, 32.2 LiO₂, 12 ZnO, 0.8P₂O₅

\[
\Delta n = \frac{1}{\sqrt{2\pi} \cdot \ln \sigma} \exp\left\{-\frac{1}{2} \left( \ln\left(\frac{x}{\bar{x}}\right)/\ln \sigma \right)^2 \right\} \Delta(\ln x)
\]
Growth of Nanocrystalline Metal at Glass-Crystal Interface

\[ \log \rho \ (\text{ohm / square}) \]

\[ T \ (\text{K}) \]

- 7.8 nm
- 11.6 nm
- 4.5 nm
- 5.7 nm
- 6.7 nm
- 8.7 nm
Growth of Nanocrystalline Metal at Glass-Crystal Interface

Electron Tunnelling between Metal Islands

*Neugebauer and Webb model:*

\[ \rho \propto \exp(2\alpha s + E / kT) \]

**Symbols:**
- \( \alpha \): Tunnelling exponent \( (=\left(\frac{2m\phi}{\hbar^2}\right)^{1/2}) \)
- \( s \): Inter-Grain distance
- \( E \): Energy to charge a grain
- \( \phi \): Effective barrier height

\[ E = \frac{e^2}{2\pi\varepsilon\varepsilon_0}\left(\frac{1}{r} - \frac{1}{r + s}\right) \quad (\text{Tick and Fehlner 1972}) \]

**Abbreviations:**
- \( e \): electronic charge
- \( r \): metal grain radius
- \( \varepsilon \): dielectric constant of matrix
- \( \varepsilon_0 \): dielectric permittivity of free space
Glass-metal nanocomposite by electrodeposition
FRACTAL GROWTH OF METAL IN GLASSES

Composition:
50AgNO3, 50SiO2
Voltage 10 V

X 1000
FRACTAL GROWTH OF METAL IN GLASSES

Gel composition: 40 AgNO3, 60 SiO2
Electrodeposition voltage 10 V
GROWTH OF SILVER NANOWIRES IN NANO CHANNELS OF FLUOROPHLOGOPITE MICA (KMg³AI₂Si₃O₁₀F₂)

GLASS COMPOSITION (TYPICAL):
42 SiO₂ 15 B₂O₃ 9Al₂O₃ 8 MgO 20 K₂O 6KF

HEAT TREATMENT AT 1168 K FOR 2 HRS

ION EXCHANGED IN AgNO₃ AT 573 K FOR 24 HRS

ELECTRODEPOSITION WITH 10 VOLTS AT 370 K
(SILVER PASTE ELECTRODES)
GROWTH OF SILVER NANOWIRES IN NANO CHANNELS OF FLUOROPHLOGOPITE MICA

Crystal Channels as Templates for Growing Nanowires
GLASS CERAMICS WITH FLUOROPHLOGOPITE MICA
NANOWIRES IN GLASS CERAMICS CONTAINING FLUOROPHLOGOPITE MICA
NANOWIRES IN GLASS CERAMICS CONTAINING FLUOROPHLOGOPITE MICA

Interplanar spacing $d_{hkl}$ Specimen
heat treated at 1165 K / 2 hr + ion exchanged at 573 K / 24 hr

<table>
<thead>
<tr>
<th>Experimental value Specimen heat treated at 1163K for 2 hr and ion exchanged at 573 K for 24 hr. (nm)</th>
<th>Standard X-ray data for $\text{K Mg}_3\text{Al Si}<em>3\text{O}</em>{10}\text{F}_2$ (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0769</td>
<td>0.996 (001)</td>
</tr>
<tr>
<td>0.4666</td>
<td>0.459 (020)</td>
</tr>
<tr>
<td>0.375</td>
<td>0.365 (112)</td>
</tr>
<tr>
<td>0.304</td>
<td>0.313 (112)</td>
</tr>
<tr>
<td>0.250</td>
<td>0.249 (131)</td>
</tr>
</tbody>
</table>
GROWTH OF SILVER NANO PARTICLES IN GLASS CERAMICS CONTAINING FLUORPHLOGOPITE MICA

GLASS COMPOSITION

47 SiO₂ 15 B₂O₃ 12Al₂O₃ 10 MgO 10 K₂O 6KF
SILVER NANOWIRES IN GLASS CERAMICS CONTAINING FLUORPHLOGOPITE MICA
SILVER NANOWIRES IN GLASS CERAMICS CONTAINING FLUORPHLOGOPITE MICA

SCHEMATIC OF BREAK JUNCTIONS

SILVER NANOWIRES IN MICA CHANNELS– ULTRA HIGH DIELECTRIC PERMITTIVITY

SPACE CHARGE POLARIZATION MODEL FAILS TO EXPLAIN HIGH $\varepsilon$

MECHANISM IS ELECTRONIC

INTERRUPTED STRAND MODEL (RICE & BERNASCONI, 1972, PRL)

$$\varepsilon \approx \frac{1}{2 (q_s l_0)^2}$$

$l_0$: STRAND LENGTH; $l_0 = 1287$ nm

$q_s$: FERMI THOMAS SCREENING WAVE VECTOR OF CONDUCTION ELECTRONS

$q_s \sim a^{-1}$ FOR METALLIC DENSITIES; FOR $\varepsilon \sim 10^7$ AND $a = 0.28$ nm

IN AGREEMENT WITH MICA CRYSTALLITE DIMENSIONS
COPPER CORE COPPER OXIDE SHELL – INTERFACIAL AMORPHOUS PHASE

**Preparation:**
*Target gel composition 60 CuO. 40 SiO₂ (mole%)*

**Precursors:** CuCl₂. 2H₂O, Si(O₂H₅)₄

**Soln:** 60 ml C₂H₅OH, 10 ml dist H₂O, 1 ml HCL, 125 ml Si (O₂H₅)₄

Reference Sample → Hot Pressed → GEL

REDCN 650°C / 30 Min

Sample (Metallic Conduction) → Hot Pressed → Nanosized Metal (Cu) (ξ=6.8 nm)

OXDN 450°C - 850°C / 30 Min

Cu₂O (CuO) coated Cu → Sample → Hot Pressed
COPPER CORE COPPER OXIDE SHELL – INTERFACIAL AMORPHOUS PHASE

SPECIMEN REDUCED AT 923K / 30MIN + OXIDIZED AT 823K / 30MIN
COPPER CORE COPPER OXIDE SHELL-INTERFACIAL AMORPHOUS PHASE

Variation of log resistivity as a function of inverse temperature for different samples.

COPPER CORE COPPER OXIDE SHELL – INTERFACIAL AMORPHOUS PHASE

NORMALIZED PLOTS OF $M'$ AND $M''$
SPECIMEN REDUCED AT 923K / 30 MIN + OXIDIZED AT 723K / 30 MIN

KWW FUNCTION: $F(t) = \exp\left[-\left(\frac{t}{\tau_R}\right)^\beta\right]$
<table>
<thead>
<tr>
<th>Model</th>
<th>N/Wt</th>
<th>$\beta_1$</th>
<th>$10^{-5} \rho_0$</th>
<th>$10^8 \tau_o$</th>
<th>$\varepsilon_{D=\infty}$</th>
<th>$\varepsilon_{Cl=\infty}$</th>
<th>$10^5 A_{SC}$</th>
<th>$\gamma_{SC}$</th>
<th>100$S_F$</th>
<th>$-FQF$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK1</td>
<td>12/P</td>
<td>{0.191}</td>
<td>3.42</td>
<td>[0.013]</td>
<td>72.5</td>
<td>0.754</td>
<td>...</td>
<td>...</td>
<td>2.98</td>
<td>89</td>
</tr>
<tr>
<td>CK1</td>
<td>12/M</td>
<td>{0.190}</td>
<td>3.33</td>
<td>[0.009]</td>
<td>74.1</td>
<td>0.602</td>
<td>...</td>
<td>...</td>
<td>2.34</td>
<td>124</td>
</tr>
<tr>
<td>CK1</td>
<td>10/P</td>
<td>[0.450]</td>
<td>3.05</td>
<td>[17.3]</td>
<td>56.8</td>
<td>16.3</td>
<td>...</td>
<td>...</td>
<td>1.87</td>
<td>96</td>
</tr>
<tr>
<td>CK1</td>
<td>10/M</td>
<td>{0.371}</td>
<td>3.04</td>
<td>[5.50]</td>
<td>64.7</td>
<td>8.49</td>
<td>...</td>
<td>...</td>
<td>1.52</td>
<td>119</td>
</tr>
<tr>
<td>CK1</td>
<td>10/P</td>
<td>(2/3)</td>
<td>3.06</td>
<td>135</td>
<td>{11.4}</td>
<td>66.0</td>
<td>...</td>
<td>...</td>
<td>2.60</td>
<td>83</td>
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<tr>
<td>CK1</td>
<td>10/M</td>
<td>(2/3)</td>
<td>3.02</td>
<td>118</td>
<td>{19.7}</td>
<td>58.7</td>
<td>...</td>
<td>...</td>
<td>1.93</td>
<td>114</td>
</tr>
<tr>
<td>CK1S</td>
<td>10/M</td>
<td>(2/3)</td>
<td>2.49</td>
<td>[59.5]</td>
<td>56.0</td>
<td>35.9</td>
<td>{1.17}</td>
<td>0.66</td>
<td>0.84</td>
<td>141</td>
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<tr>
<td>CK1S</td>
<td>10/M</td>
<td>0.676</td>
<td>2.55</td>
<td>68.3#</td>
<td>51.3#</td>
<td>39.6</td>
<td>(1.81)</td>
<td>0.64</td>
<td>0.90</td>
<td>138</td>
</tr>
<tr>
<td>CK1</td>
<td>10/P</td>
<td>(1/3)</td>
<td>3.10</td>
<td>2.94</td>
<td>65.8</td>
<td>6.43</td>
<td>...</td>
<td>...</td>
<td>1.97</td>
<td>94</td>
</tr>
<tr>
<td>CK1</td>
<td>10/M</td>
<td>(1/3)</td>
<td>3.06</td>
<td>2.67</td>
<td>67.4</td>
<td>5.90</td>
<td>...</td>
<td>...</td>
<td>1.53</td>
<td>120</td>
</tr>
<tr>
<td>CK1S</td>
<td>10/M</td>
<td>(1/3)</td>
<td>2.58</td>
<td>[1.40]</td>
<td>82.0</td>
<td>3.96</td>
<td>{1.53}</td>
<td>0.65</td>
<td>0.90</td>
<td>137</td>
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<tr>
<td>CK1S</td>
<td>10/M</td>
<td>0.438</td>
<td>2.57</td>
<td>8.56</td>
<td>76.4</td>
<td>9.92</td>
<td>(1.53)</td>
<td>0.66</td>
<td>0.77</td>
<td>143</td>
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<tr>
<td>CK1S</td>
<td>12/P</td>
<td>0.333</td>
<td>2.82</td>
<td>2.14</td>
<td>73.9</td>
<td>5.14</td>
<td>[1.42]</td>
<td>0.70</td>
<td>2.03</td>
<td>106</td>
</tr>
<tr>
<td>CK1S</td>
<td>12/P/Y</td>
<td>{0.331}</td>
<td>2.97</td>
<td>[2.46]</td>
<td>{69.8}</td>
<td>5.90</td>
<td>[1.58]</td>
<td>{0.73}</td>
<td>2.03</td>
<td>106</td>
</tr>
</tbody>
</table>

**Fe - Fe₃O₄ - SiO₂ Gel Nanocomposites**

**Target Composition**: 55 Fe₂O₃, 45 SiO₂ (mol %)

**Soln A**: 60 ml C₂H₅OH, 10ml H₂O, 23.17 gm FeCl₃

**Soln B**: 90 ml C₂H₅OH, 15ml H₂O, 1 ml HCL, 26.2 ml Si(OC₂H₅)₄

**Soln. A + Soln. B**

- Ref. Sample at 1123K / 2hr
- 2 weeks for gelation

- Powder Hot Pressed
- Redcn in H₂ at 923 K / ½ hr
- (Metallic Conduction)
- Oxdn at 573 K / ½ hr
- Powder Hot Pressed at 923K / 5 min
<table>
<thead>
<tr>
<th>Heat treatment Schedule for gel powder before hot pressing</th>
<th>Median Diameter ( X ) (nm)</th>
<th>Geometric Standard Deviation ( \sigma )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced at 923 K / ( \frac{1}{2} ) hr</td>
<td>5.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Reduced at 923 K / ( \frac{1}{2} ) hr</td>
<td>4.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Oxidized at 823 K / ( \frac{1}{2} ) hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced at 923 K / ( \frac{1}{2} ) hr</td>
<td>4.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Oxidized at 1023 K / ( \frac{1}{2} ) hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced at 923 K / ( \frac{1}{2} ) hr</td>
<td>4.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Oxidized at 1123 K / ( \frac{1}{2} ) hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced at 923 K / ( \frac{1}{2} ) hr</td>
<td>4.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Oxidized at 1123 K / ( \frac{1}{2} ) hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced at 923 K / ( \frac{1}{2} ) hr</td>
<td>4.1</td>
<td>1.4</td>
</tr>
</tbody>
</table>
Fe-Fe$_3$O$_4$/SiO$_2$ Nanocomposites

Fe - Fe$_3$O$_4$ - SiO$_2$ Gel Nanocomposites

<table>
<thead>
<tr>
<th>specimen</th>
<th>W (cV)</th>
<th>$\alpha$ (AU$^{-1}$)</th>
<th>R (AU)</th>
<th>C</th>
<th>$\nu_o$ (s$^{-1}$)</th>
<th>$\varepsilon_\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref</td>
<td>0.39</td>
<td>0.95</td>
<td>4.7</td>
<td>0.99</td>
<td>1.2x10$^{13}$</td>
<td>4.9</td>
</tr>
<tr>
<td>2</td>
<td>0.08</td>
<td>0.89</td>
<td>4.7</td>
<td>0.99</td>
<td>1.3x10$^{13}$</td>
<td>23.8</td>
</tr>
<tr>
<td>3</td>
<td>0.08</td>
<td>0.86</td>
<td>4.8</td>
<td>0.99</td>
<td>1.2x10$^{13}$</td>
<td>23.3</td>
</tr>
<tr>
<td>4</td>
<td>0.07</td>
<td>0.87</td>
<td>4.9</td>
<td>0.99</td>
<td>1.1x10$^{13}$</td>
<td>26.1</td>
</tr>
<tr>
<td>5</td>
<td>0.06</td>
<td>0.86</td>
<td>4.8</td>
<td>0.99</td>
<td>1.3x10$^{13}$</td>
<td>31.1</td>
</tr>
</tbody>
</table>

Small polaron Hopping

$$\rho = \frac{kTR}{\nu_o c^2 c(1-c)} \exp(2\alpha R) \exp\left(\frac{W}{kT}\right)$$

$$W \approx \frac{e^2}{4\varepsilon_\rho \gamma_p}$$

$$\gamma_p = \frac{1}{2} \left(\frac{\Pi}{6}\right)^{\frac{1}{3}} R$$
IRON-IRON OXIDE NANO CORE-SHELL STRUCTURE

Optical micrograph of film with fractally grown Fe-Fe$_3$O$_4$ core shell structure
IRON-IRON OXIDE NANO CORE-SHELL STRUCTURE

AFM micrograph
IRON-IRON OXIDE NANO CORE-SHELL STRUCTURE

TEM of the specimen
IRON-IRON OXIDE NANO CORE-SHELL STRUCTURE

TEM of core shell structure
IRON-IRON OXIDE NANO CORE-SHELL STRUCTURE

Electron diffraction pattern IRON-IRON OXIDE NANO CORE-SHELL STRUCTURE
Surface resistivity as a function of temperature

- ▼ Reference
- Specimen
- O 1 hour oxidation
- □ 2 hour oxidation
- △ 4 hour oxidation
IRON-IRON OXIDE NANO CORE-SHELL STRUCTURE

Surface resistivity vs. relative humidity

- ▽ Reference Specimen
- ○ 1 hour oxidation
- □ 2 hour oxidation
- △ 4 hour oxidation

SILVER / SILICATE GLASS CERAMIC NANOCOMPOSITES

COMPOSITION:

10 Na$_2$O, 34 BaO, 34 TiO$_2$, 17 B$_2$O$_3$, 5 SiO$_2$

Heat treatment at 843 K and 963 K

Powdered samples ION Exchanged at 583 K / 6 Hrs

Reduction at 573 K / 5 Min.s
SILVER / SILICATE GLASS CERAMIC NANOCOMPOSITES

SEM Micrograph of Glass Ceramic

X Ray Diffractogram of Glass Ceramic

Crystalline phases: $\text{Na}_2\text{B}_4\text{O}_7$; $\text{BaTiO}_3$
a) TEM of ION Exchanged and reduced Glass Ceramic
b) Electron Diffraction of (a)
SILVER / SILICATE GLASS CERAMIC NANOCOMPOSITES

Histogram of Silver Particle Size
Table II

Summary of heat treatment schedules for crystallization and median diameter $\bar{x}$ and geometric standard deviation $\sigma$ obtained for different specimens after ion exchange/reduction treatment

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Heat Treatment</th>
<th>$\bar{x}$ (nm)</th>
<th>$\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>843K for 2 hours + 963K for 10 min.</td>
<td>3.4</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>843K for 4 hours + 963K for 10 min.</td>
<td>4.6</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>843K for 6 hours + 963K for 15 min.</td>
<td>10.1</td>
<td>1.3</td>
</tr>
<tr>
<td>4</td>
<td>843K for 2 hours + 963K for 20 min.</td>
<td>13.2</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Reduction in Hydrogen at 573 K / 5 Min.s
Resistivity vs. Relative Humidity
Surface Resistivity vs. $T^{-1/4}$

Particle Diameter 3.4 nm
Current vs. Time
Silver Particle Diameter 10.1 nm
Relative Humidity 85 %
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

GLASS COMPOSITION: 30 Li₂O 12 CaO 3 Al₂O₃ 55 SiO₂

ION EXCHANGED IN AgNO₃ AT 573 K FOR 11 HRS

ELECTRODEPOSITION AT 600 K, 5 AND 10 VOLTS FOR 10 HRS
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

TEM
OF SILVER NANO ARRAYS
TEM OF NANO ARRAYS OF SILVER IN SILICATE GLASS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

TEM OF SILICA GEL GLASS WITH COPPER NANO ARRAYS

COMPOSITION: $30\text{Cu(NO}_3\text{)}_2 70\text{SiO}_2$

ELETRODEPOSITION VOLTAGE: 5 VOLTS
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

GLASS COMPOSITION
30Li$_2$O 12CaO 3Al$_2$O$_3$ 55SiO$_2$

ELECTRO DEPOSITION
VOLTAGE : 5 VOLTS

- △ 191 K
- □ 161 K
- ○ 138 K
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

DIODE LIKE BEHAVIOUR

SCHEMATIC REPRESENTATION OF METAL SEMICONDUCTOR NANO JUNCTION ARRAYS

SYMMETRICAL NON LINEAR V - I
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

ELECTRODEPOSITION AT 10 VOLTS

30 Li_2O 12CaO 3Al_2O_3 55SiO_2

208 K
167 K
125 K
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

\[ 30\text{Cu(NO}_3\text{)}_2 \cdot 70\text{SiO}_2 \text{ GEL} \]

ELETRODEPOSITION AT 5 VOLTS

NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

30Cu(NO₃)₂ . 70SiO₂ GEL
ELETRODEPOSITION AT 10 VOLTS
NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

DATA FITTED TO

\[ I = I_0 \left[ \exp \left( \frac{eV}{nkT} \right) - 1 \right] \]

<table>
<thead>
<tr>
<th>COMPOSITION</th>
<th>ELECTRO DEPOSITION VOLTAGE</th>
<th>( I_0 ) (Amp)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0.5 X 10^{-3}</td>
<td>30</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0.2 X 10^{-3}</td>
<td>60</td>
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<td>0.7 X 10^{-7}</td>
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<td>10</td>
<td>0.07 X 10^{-7}</td>
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NANO INTERFACES IN GLASS METAL NANOCOMPOSITES

ELECTRODEPOSITION
VOLTAGE 5 VOLTS

TEM OF A NANO INTERFACE
BETWEEN TWO COPPER PARTICLES
CONCLUSIONS

- A Variety of Nanostructures can be generated using a Silicate glass as template.
- Novel Properties are exhibited by the nanocomposites.
- The approach will lead to new functionality in Glasses.