Crystal Nucleation Of Palladium-Doped Lithium Disilicate Glass

Greg Humble
Advisor: Dr. Kisa Ranasinghe
What is glass?
Lithium Disilicate Glass

\[ \text{Li}_2\text{O} \cdot 2\text{SiO}_2 \]
Why study glass?

Electronics and Communication

Nuclear Waste Storage

Bioactive Materials

Precision Optics
Heterogeneous Nucleation with Impurities

$\text{Li}_2\text{O} \cdot 2\text{SiO}_2 + 0.001\% \text{ Pd}$
Heated to 1200°C for 3 hours
Quenched on a stainless steel plate
Heterogeneous Nucleation with Impurities

Effect of temperature on the enthalpy of a glass forming melt
Nucleation and Crystal Growth Rates

Effect of temperature on the rates of nucleation and crystal growth for a glass forming melt
Glass Sample Preparation

Final Sample Size ~400μm
Testing Apparatus

Differential Scanning Calorimeter
DSC graph for typical 20°C/min scan

- **Crystallization Peak**
- **Glass Transition**
Crystal Nucleation

\[ V_{g1} = V_0 - V_{C1} \]

\[ V_{g1} = V_0 \left[ 1 - \frac{\pi}{3} (I_N t_N + N_q)(U_N t_N)^3 \right] \]
Stages of Heating

- Fast Quench
- Nucleation
- Crystal Growth
- Room Temperature

Temperature (T) vs. Time

- Tm
- To
- TN
- 525°C
- 750°C

Graph showing the transition from glass to crystal growth with temperature changes over time.
Calculating $N_q$

\[ N = \left( \frac{A_1 m_2}{A_2 m_1} \right)^{-1} \]

\[ = \frac{A_1 m_2}{A_2 m_1} \left[ \frac{4}{3} \pi (U_G t_2) \right] - \frac{4}{3} \pi (U_G t_1) \]
## Data for 480°C

Nucleation Temperature: 480 °C

<table>
<thead>
<tr>
<th>t_(N) (min)</th>
<th>A1(300)</th>
<th>A2(600)</th>
<th>m1 (mg)</th>
<th>m2 (mg)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>207.8000</td>
<td>133.1000</td>
<td>27.4640</td>
<td>22.8560</td>
<td>3.40E+012</td>
</tr>
<tr>
<td>30</td>
<td>181.2000</td>
<td>123.1000</td>
<td>22.2770</td>
<td>23.4100</td>
<td>5.13E+012</td>
</tr>
<tr>
<td>60</td>
<td>199.6000</td>
<td>102.8000</td>
<td>26.5640</td>
<td>26.5830</td>
<td>6.92E+012</td>
</tr>
<tr>
<td>90</td>
<td>213.6000</td>
<td>130.4000</td>
<td>25.1530</td>
<td>22.2070</td>
<td>4.50E+012</td>
</tr>
<tr>
<td>120</td>
<td>208.8000</td>
<td>117.6000</td>
<td>22.5540</td>
<td>30.1690</td>
<td>8.15E+012</td>
</tr>
<tr>
<td>150</td>
<td>203.2000</td>
<td>115.7000</td>
<td>19.8770</td>
<td>17.6850</td>
<td>5.22E+012</td>
</tr>
<tr>
<td>180</td>
<td>194.9000</td>
<td>89.2400</td>
<td>29.9450</td>
<td>32.2360</td>
<td>8.09E+012</td>
</tr>
<tr>
<td>240</td>
<td>193.1000</td>
<td>107.6000</td>
<td>27.9390</td>
<td>23.4840</td>
<td>4.90E+012</td>
</tr>
<tr>
<td>360</td>
<td>181.7000</td>
<td>82.8300</td>
<td>29.9260</td>
<td>26.8950</td>
<td>7.02E+012</td>
</tr>
</tbody>
</table>
Nuclei Vs Time at 480°C
Discussion

![Graph showing nucleation rate vs temperature](image)
Discussion

Nq without Pd = $1.63 \times 10^{12}$ m$^{-3}$
Nq with Pd = $2.60 \times 10^{12}$ m$^{-3}$
Acknowledgements

College of Science and Mathematics

Physics Department

Dr. Kisa Ranasinghe

Shawn Phillips & Nick Roth