Improving Electric Melting for the Future of Glass Manufacturing

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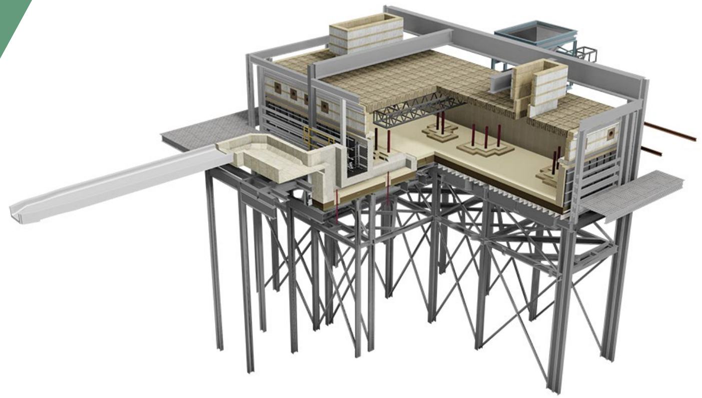


U.S. DEPARTMENT OF ENERGY

GMIC GLASS MANUFACTURING INDUSTRY COUNCIL

Pacific Northwest NATIONAL LABORATORY

TECO Toledo Engineering Co., Inc.

CelSian

RoMan MANUFACTURING

Developments in Glass Industry Funding 2025

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

GMIC begins $3 million electric glass melting project

Published 21st February, 2025 by Jess Mills

The cold-top furnace was set up at the University of Toledo, Ohio, USA.

GLASS MANUFACTURING INDUSTRY COUNCIL

$3M

OCED
Office of Clean Energy Demonstrations

US glassmakers in decarbonisation funding success

Published 25th March, 2024 by Greg Morris

Three US glass manufacturers: O-I Glass, Gallo Glass and Libbey can proceed with their decarbonisation projects thanks to the investment by President Biden earlier. Image from Adobe Stock.

Trump admin cuts $3.7B for industrial decarbonization and carbon capture

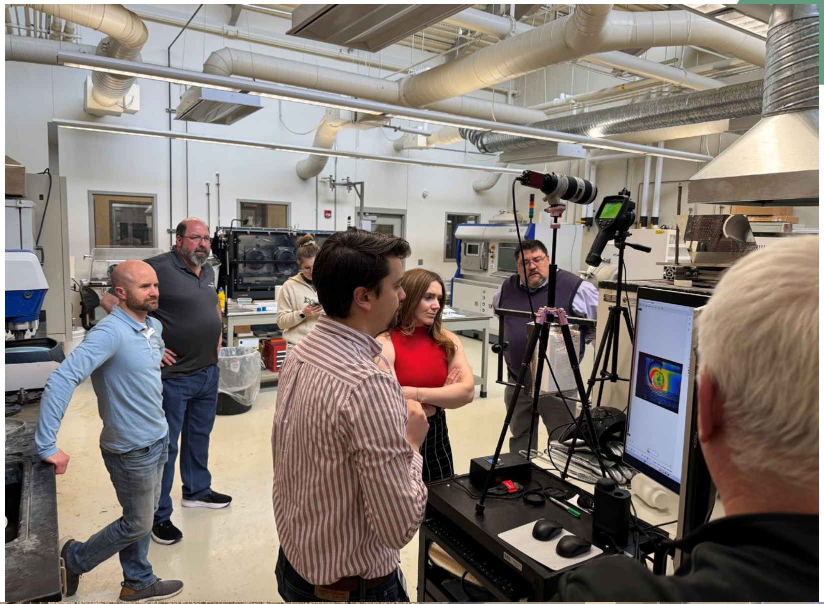
The decision will devastate ambitious efforts to cut emissions from heavy industry ranging from food production to chemicals.

By Jeff St. John
30 May 2025

Energy Secretary Chris Wright in early May. (Tom Williams/CQ-Roll Call, Inc via Getty Images)

3 companies,
Up to $245M

Industry / National Lab Team



Core Project Team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CelSian


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Stakeholders


Kerry Ward
GMIC


Keith Jameson
DOE

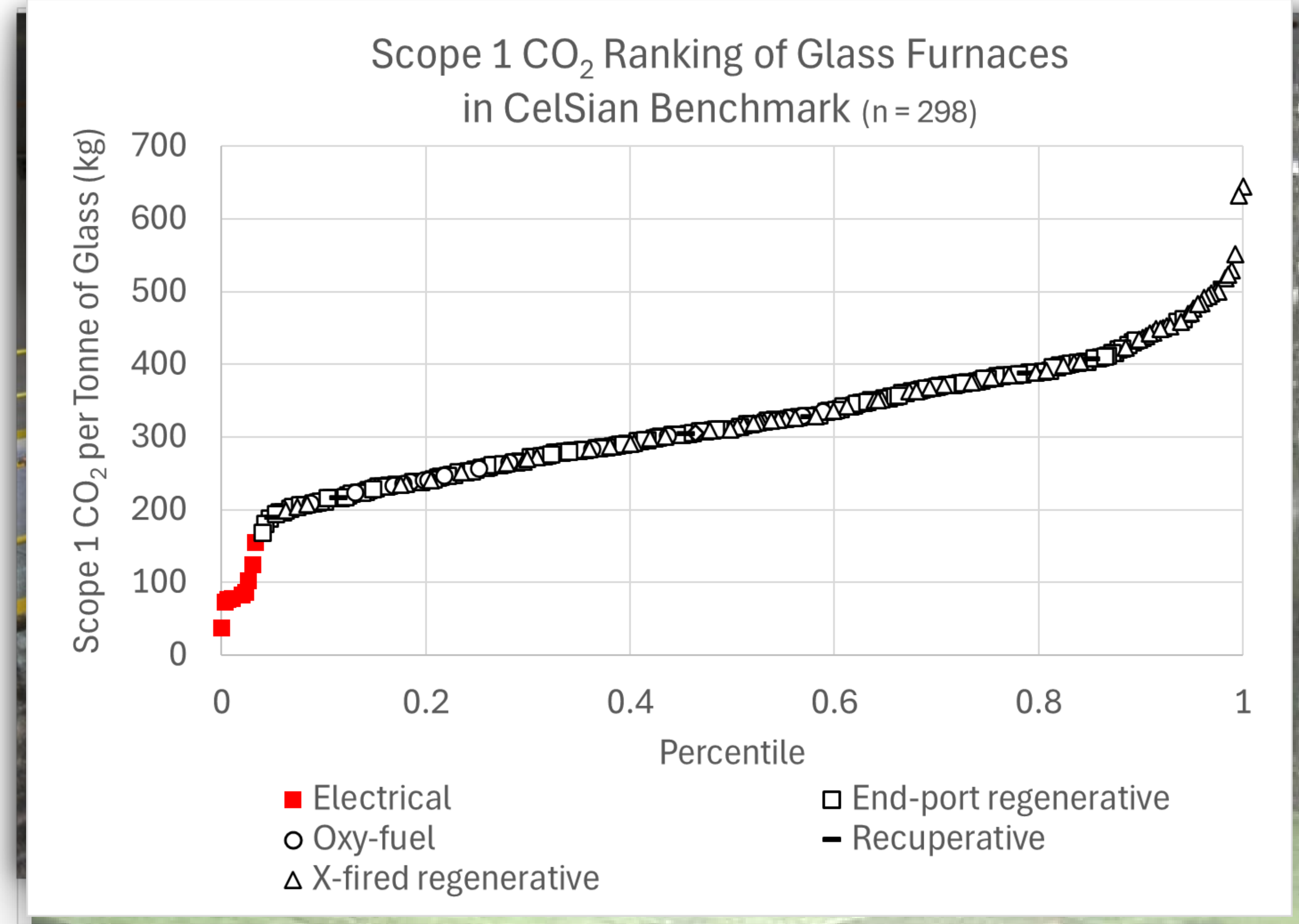

Lexie Kim
DOE

GMIC Industrial Steering Committee

- Aaron Huber (Johns Manville)
- Bruno Purnode (Owens Corning)
- Jan Schep (O-I)
- Ufuk Senturk (Potters Industries)
- Darryl Shaffer (Gallo Glass)
- Roberto Cabrera (Vitro)

Industrial Electric Melting of Glass

- Air emissions (NOx, SOx)
- Energy efficiency
- Operational ease
- Fast rebuild time
- Scope 1 CO_2 reduction



Shifting Industry Perception

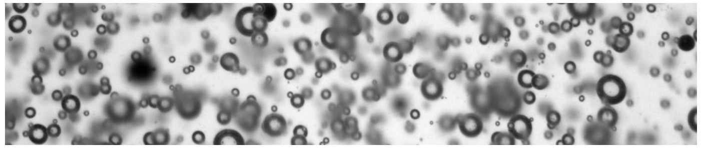
Reduced Glasses

How to avoid foaming for reduced chemistries?

How to make amber glass in a stable way?

Fiberglass
Container

Quality

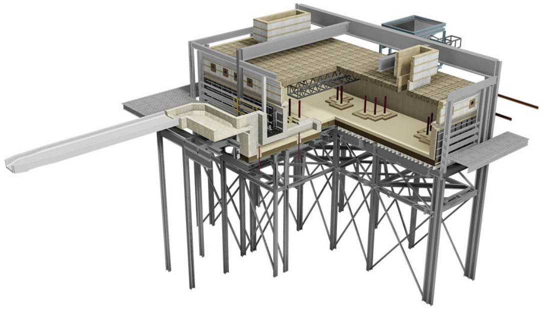


How to trigger fining in electric melters?

Reduce bubble content for oxidized glasses

Flat glass
Container
Tableware
DIsplay

Total Cost of Ownership



How to optimize:
Specific pull rate, furnace life
rebuild rate

All segments

Project Phases

BP 1	BP 2	BP 3
Exploring Concepts	Validating Concepts	Conceptual Designs

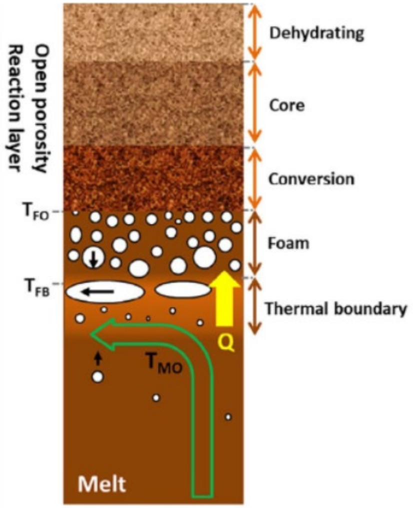
10/24 — 3/26 — 6/27 — 6/28

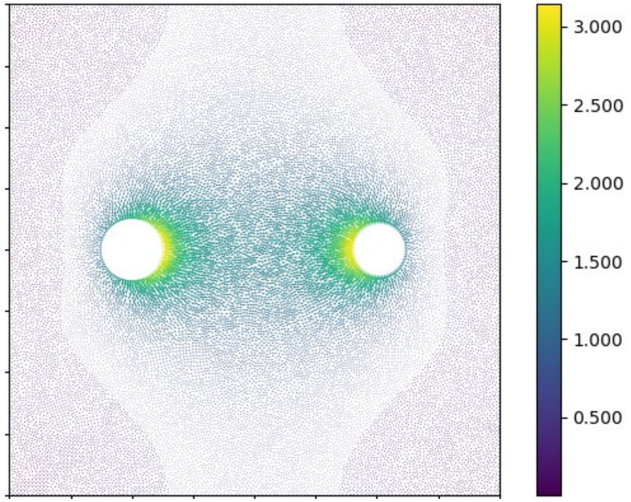
In scope:

Batch chemistries

Applied electricity

CFD modeling capability



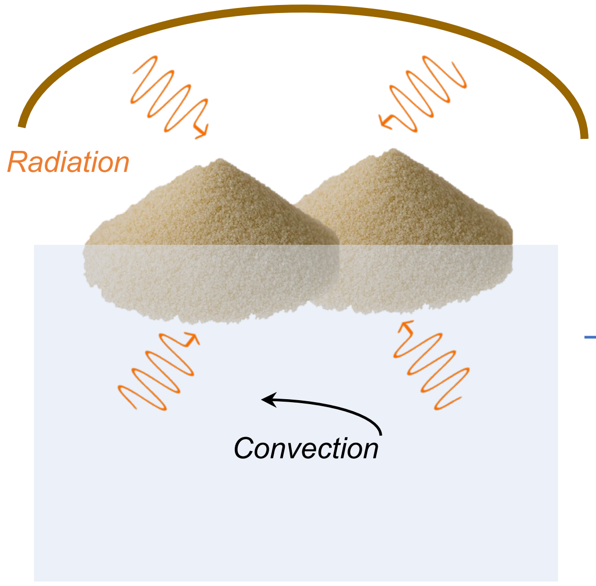


Hrma, et al. (2019).. Journal of the American Ceramic Society. 102.

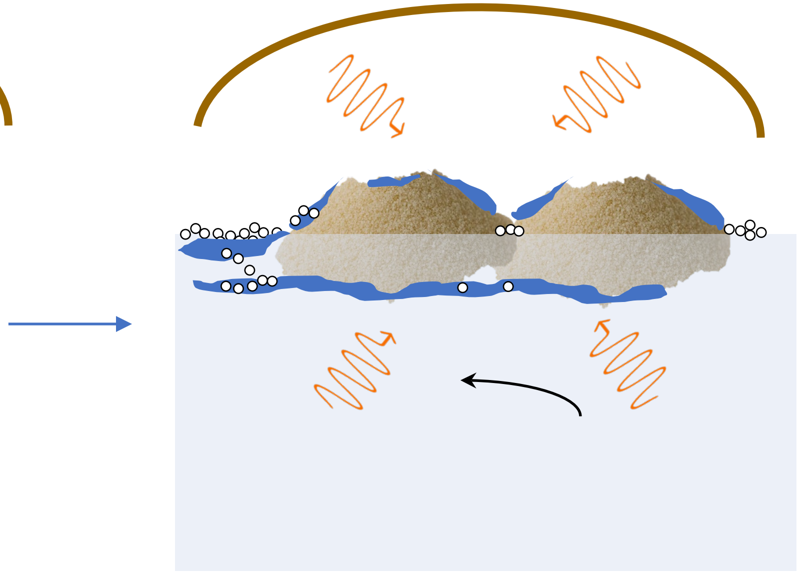
Chemistry of Cold-Top Melting

SCOTT COOPER

Heat Transfer – Hot Top



Heating from all directions (x, y, z)

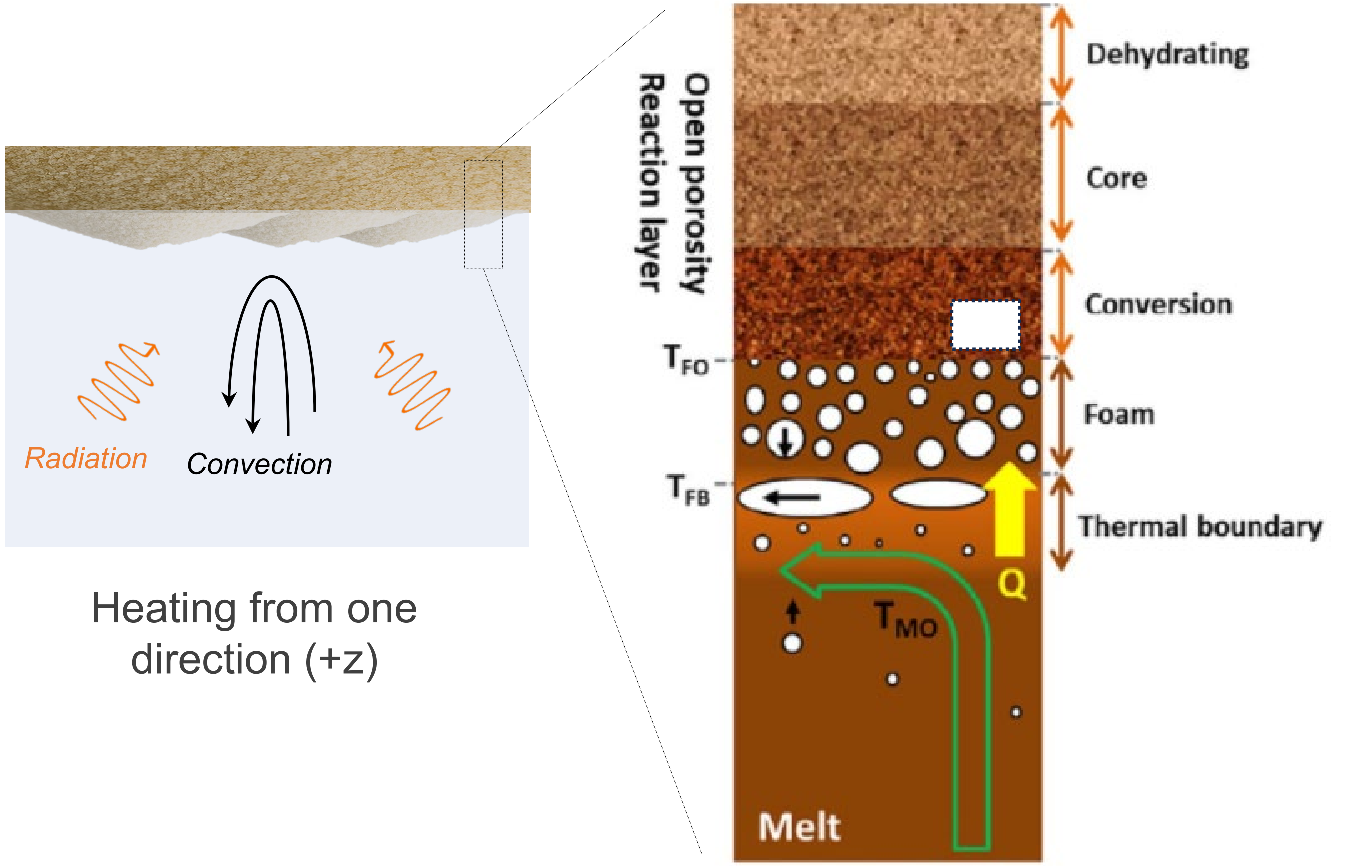


New glass rolls off piles
Primary foaming gases escape

<u>Melting good glass:</u>

- ✓ Tall, ridged batch piles
- ✓ Minimize foam coverage
- ✓ Homogeneously mixed batch
- ✓ Hot spot with adequate time, temperature (triggers secondary fining)

Heat Transfer – Cold Top



Heating from one direction (+z)

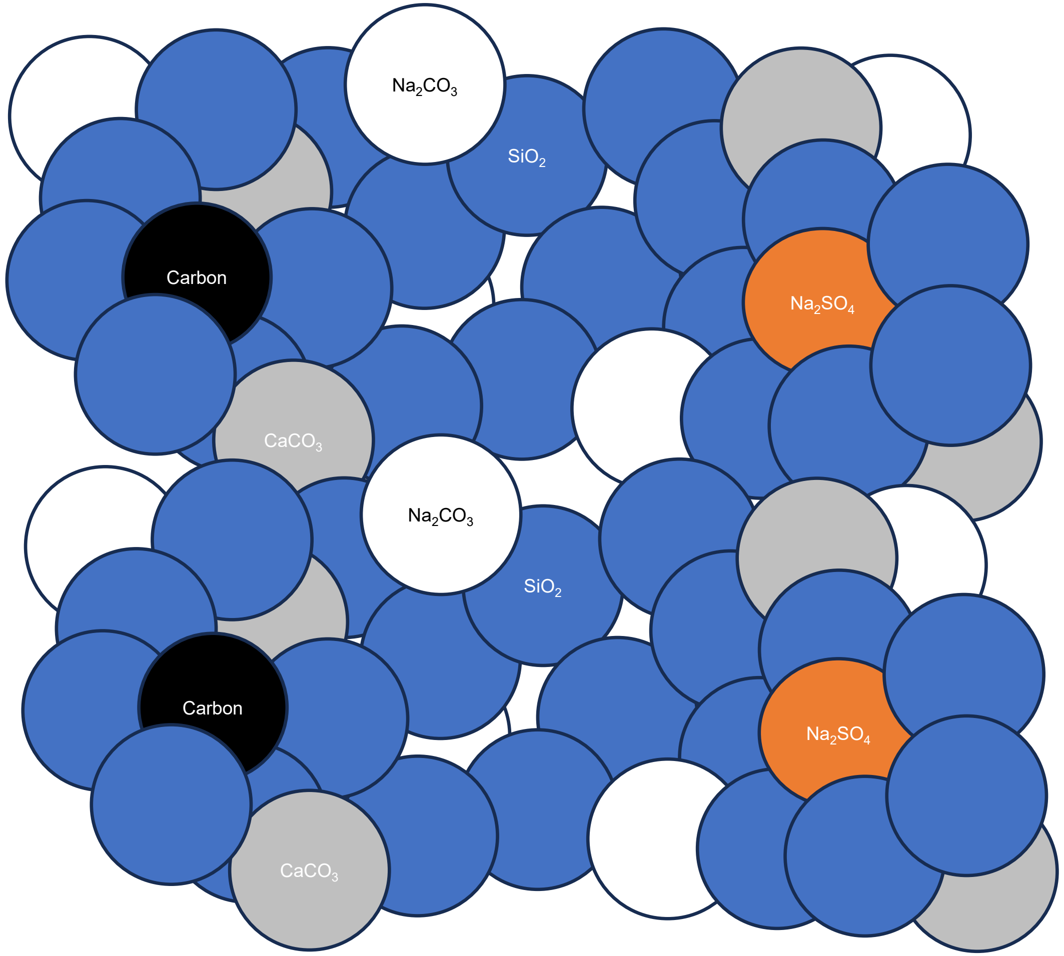
et al. (2019).. Journal of the American Ceramic Society. 102.

Melting good glass:

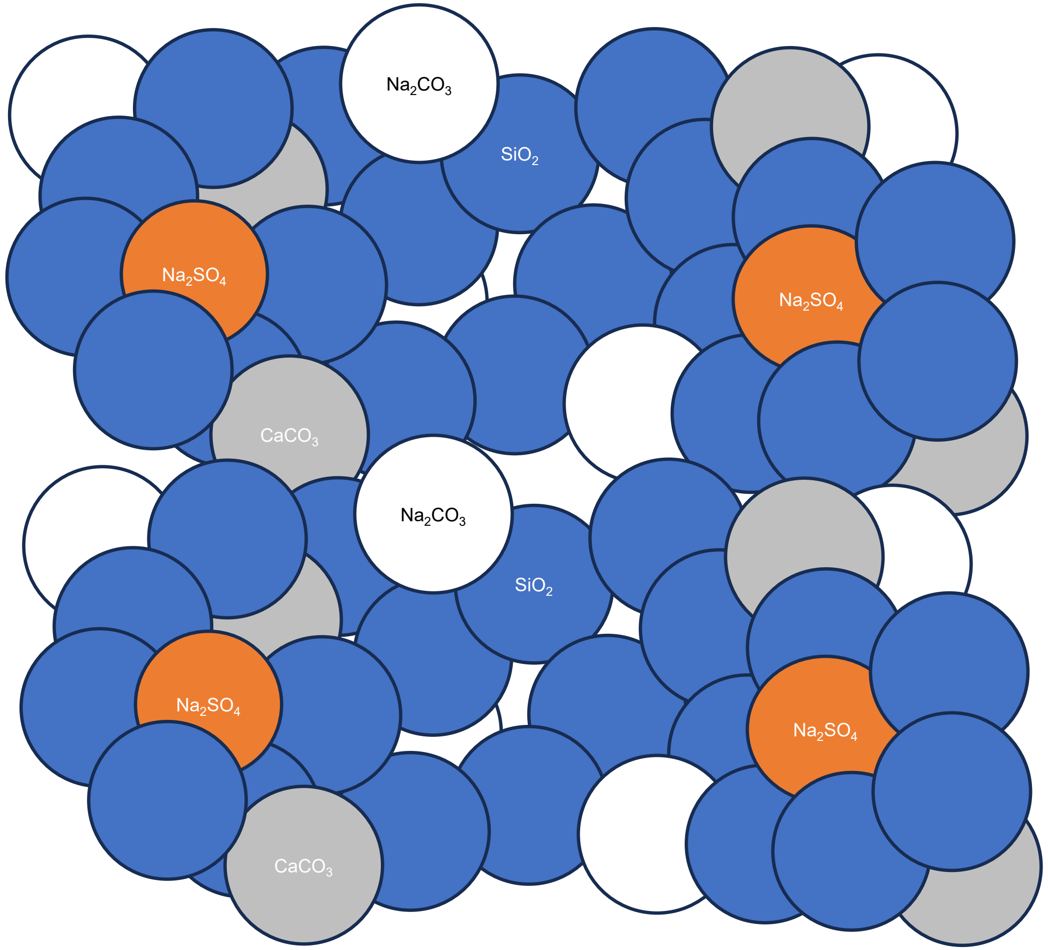
- ✓ Temperature at foam layer bottom
- ✓ Convection underneath the foam layer
- ✓ Thinner foam layer
- ✓ Avoiding redox changes

Batch: Prior to Melting Onset

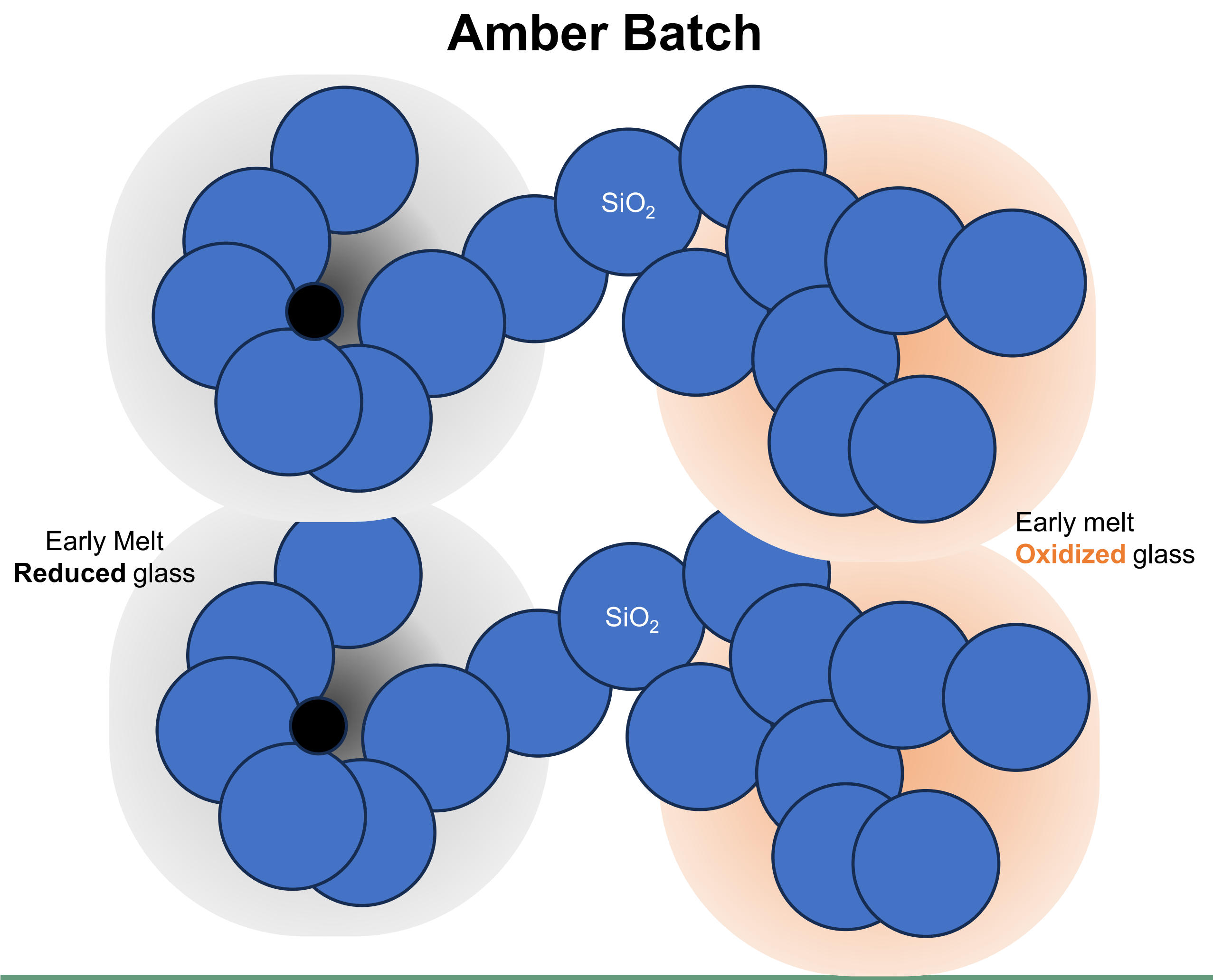
Amber Batch

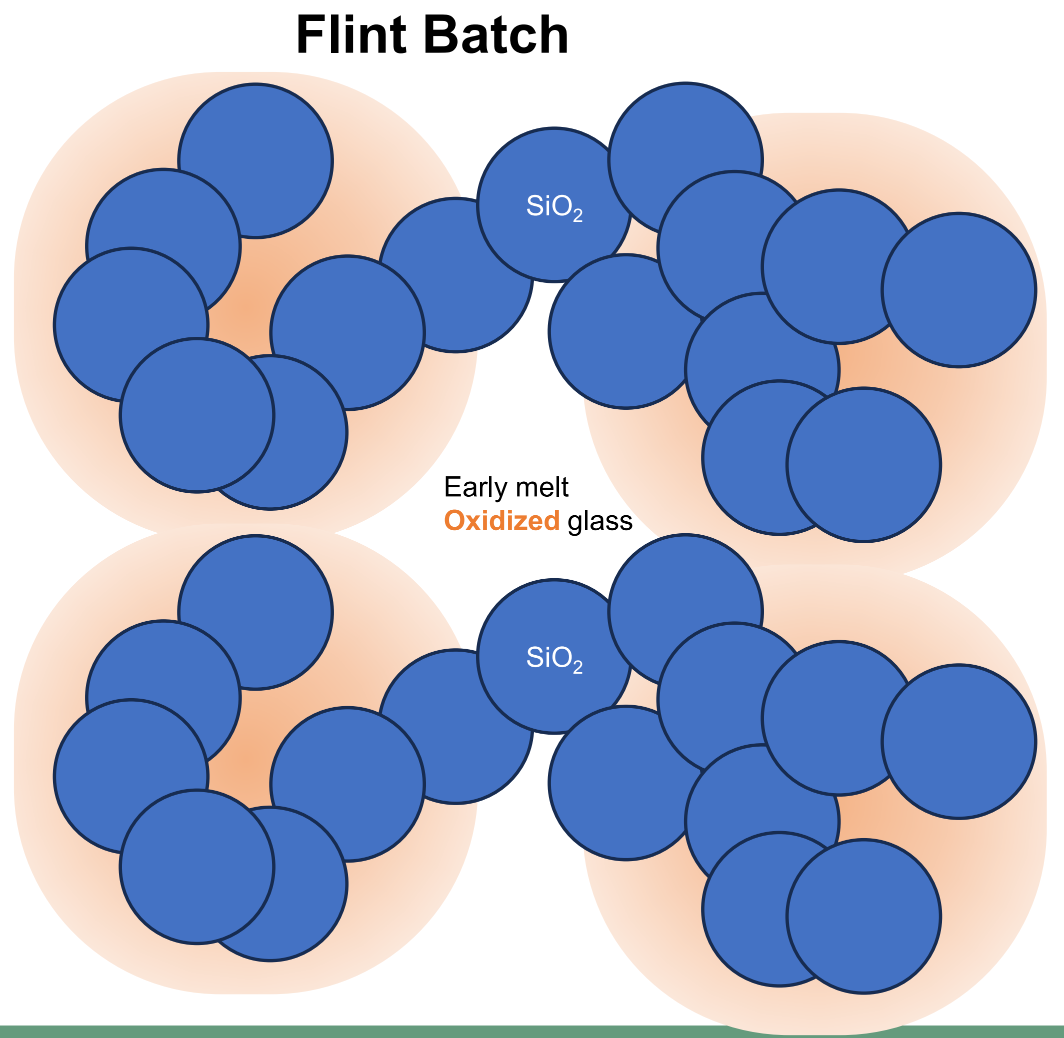


Flint Batch



Early Glass Melting Onset



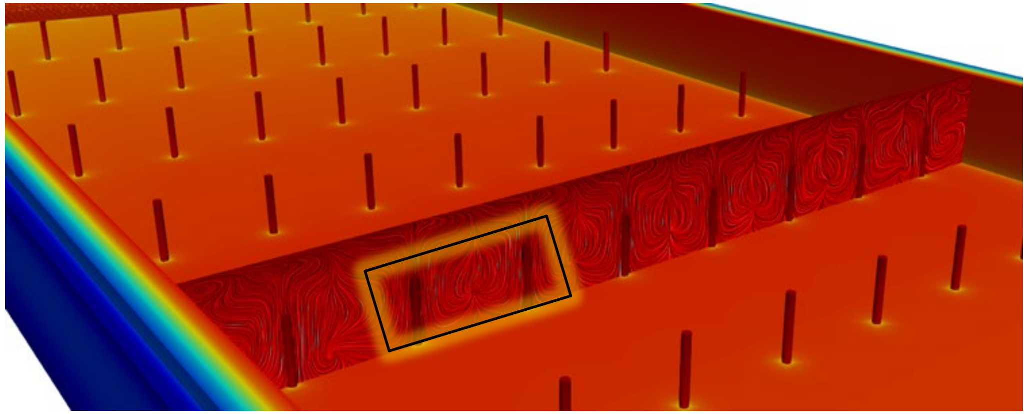


Physics of Electricity in Molten Glass

KATELYN KIRCHNER

The Glass Experience | Combustion vs. Electric

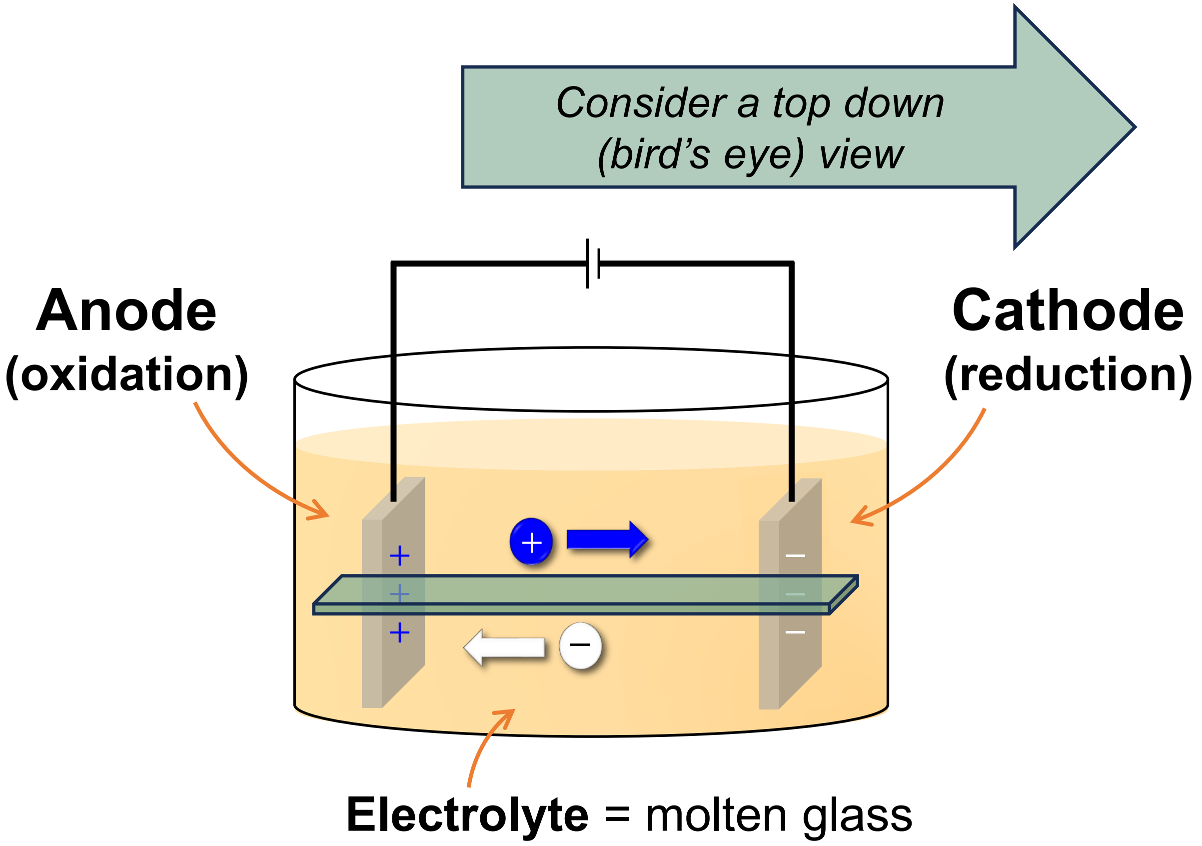
- Growing market interest in fully electric melting, which involves different heating mechanisms than standard combustion melting.

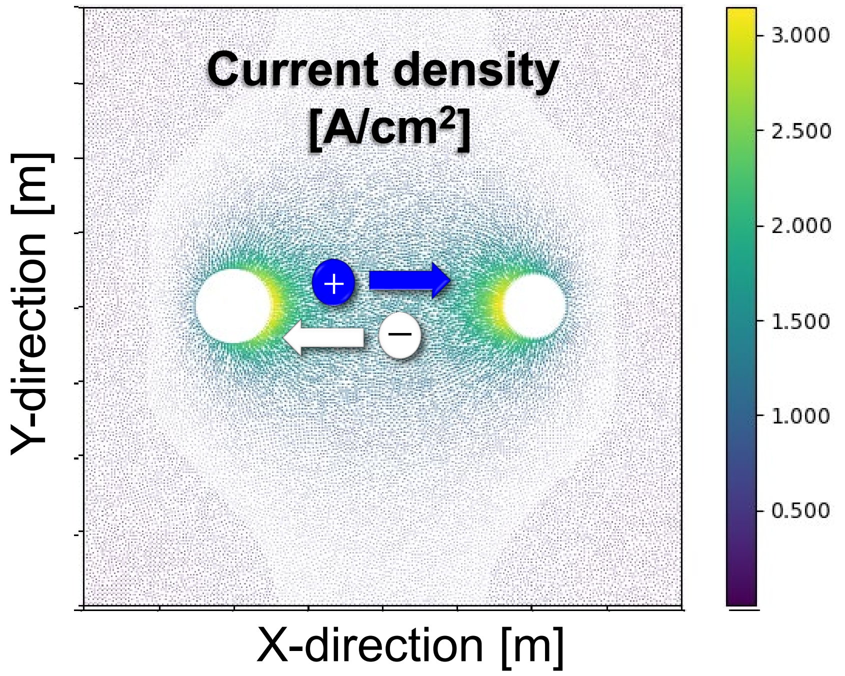


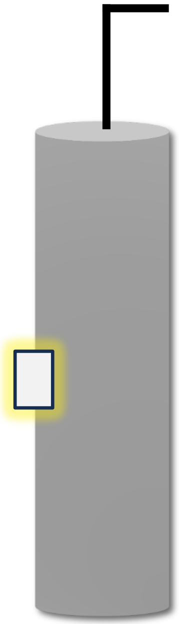
*Created using CelSian GTM-X

Consider Glass in an Electrochemical Cell

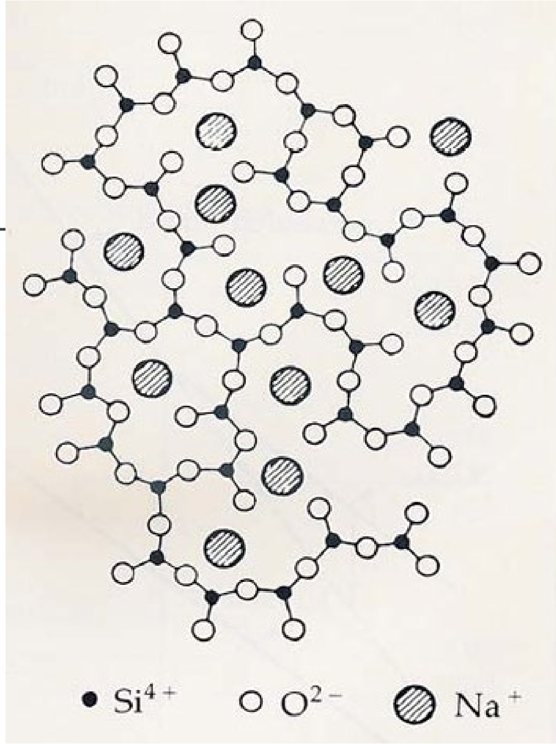
- Zoom in to what is happening at the electrode surface.
- Fundamentals are analogous to an electrochemical cell, with molten glass as the electrolyte.





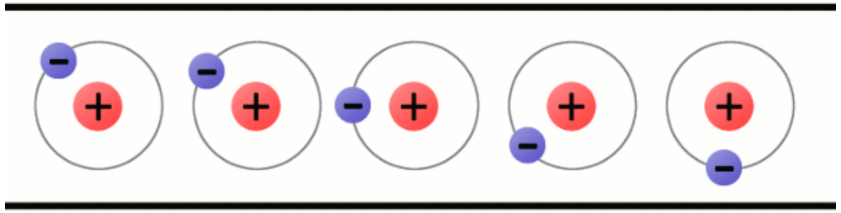


Current through Glass is Ionic



In Metals

- Available charge carriers are electrons



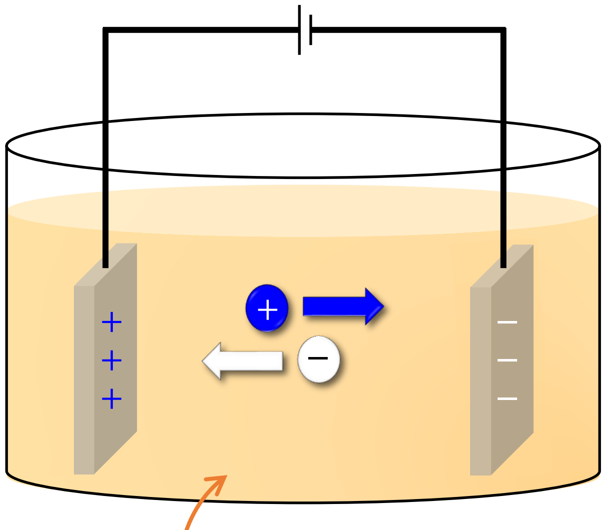
In Glass

- In liquid state, network connectivity is flexible, but electrons remain bound in bonds
- Glass has a network of strong covalently-bonded network formers [e.g., SiO_2, B_2O_3, P_2O_5]
- Glass has weakly ionically bonded modifiers [e.g., R = Na^+, Li^+, K^+, Ca^{2+}]
- Available charge carriers: R^+ or O^{2-} ions

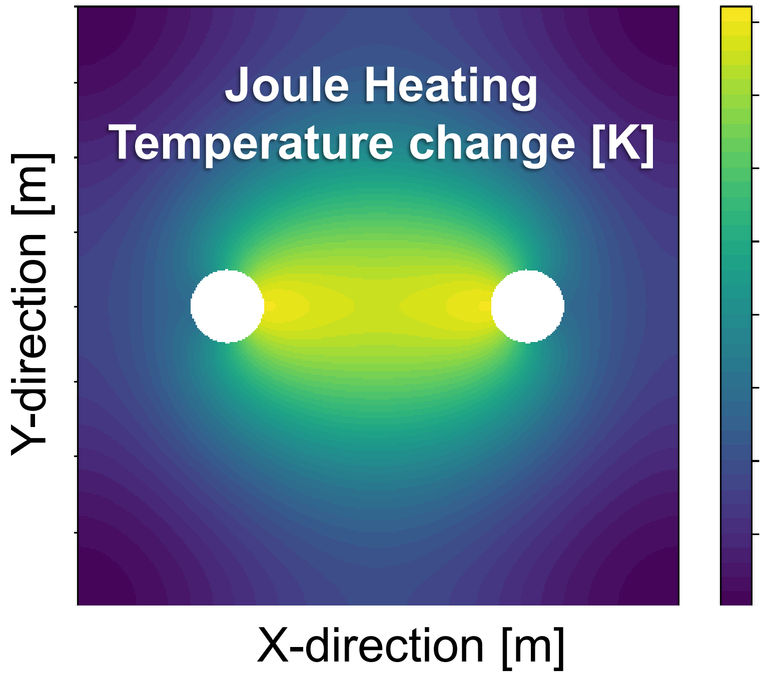
Ion Bombardment Induces Joule Heating

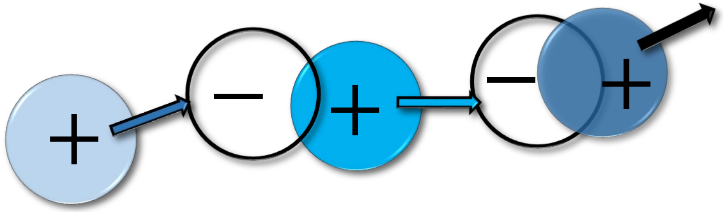
When an electric current passes through resistive glass, electrical energy is converted into heat energy

- Glass has finite electrical resistance, so it resists current
- Energy transfer: Kinetic energy of moving ions transforms into lattice vibrations (phonons)
- Result: Local heating spreads, raising the glass temperature.



Electrolyte = molten glass





Joule heating

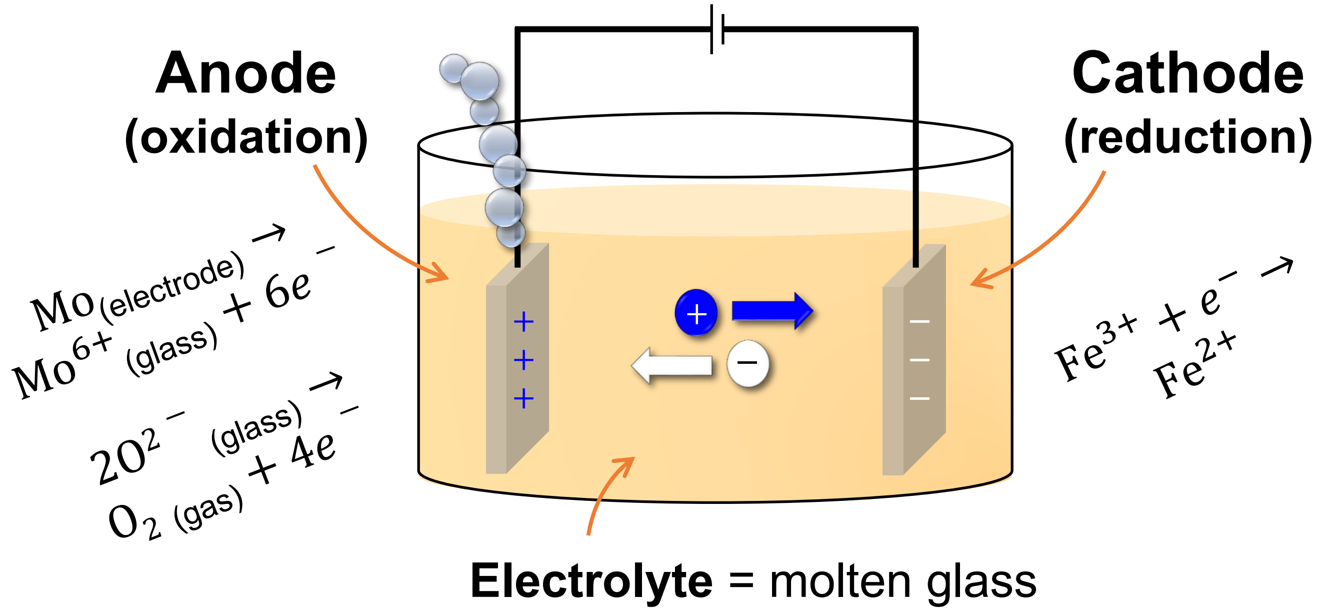
$$Q = I^2Rt$$

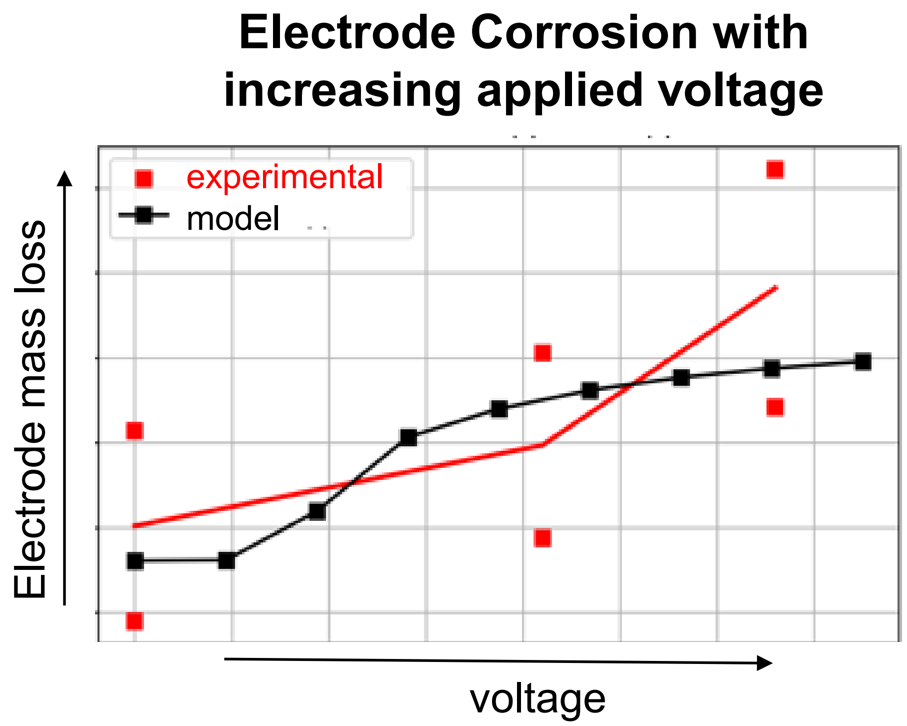
Q = heat energy generated [J]
I = electric current through the conductor [A]
R = electrical resistance of the conductor [Ω]
t = time for which the current flows [s]

Movement of Charge Induces Electrochemical Reactions

Mapping the glass experience:

Electrical potential -> current density -> joule heating -> reaction rates for mechanisms of corrosion

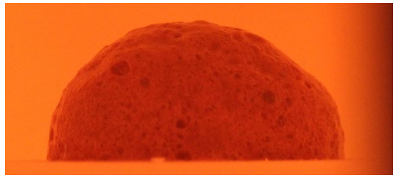




Impact for Manufacturing

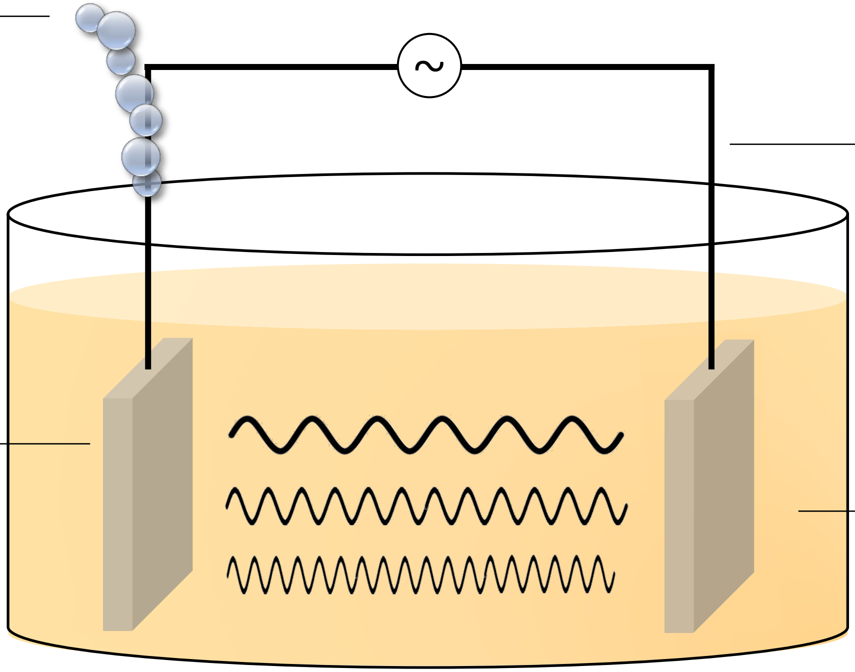
Bubbling / Foaming

To what extent is the heating method contributing to the foaming behavior



Corrosion

Can applied frequency outpace the kinetics driving electrode corrosion



Firing conditions

What electrode placement, phase angle, frequency, amplitude, etc. enable highest efficiency melting

Redox

Can we favor particular electrochemical reactions control redox of the bulk melt

H. Sesigur, F. Akmaz Sisecam

M.-C. Bölitz. Korrosion von Molybdän- und Platinelektroden in Kalknatron- und Borosilicatglas. (Dissertation, 2013 , Universität Bayreuth, Fakultät für Ingenieurwissenschaften)

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