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Glass: A Common Material Solving An Uncommon Problem – How Do We Immobilize Nuclear Waste?

Jaime George, Materials Scientist
Pacific Northwest National Laboratory

U.S. DEPARTMENT OF ENERGY BATTELLE

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1 of 17

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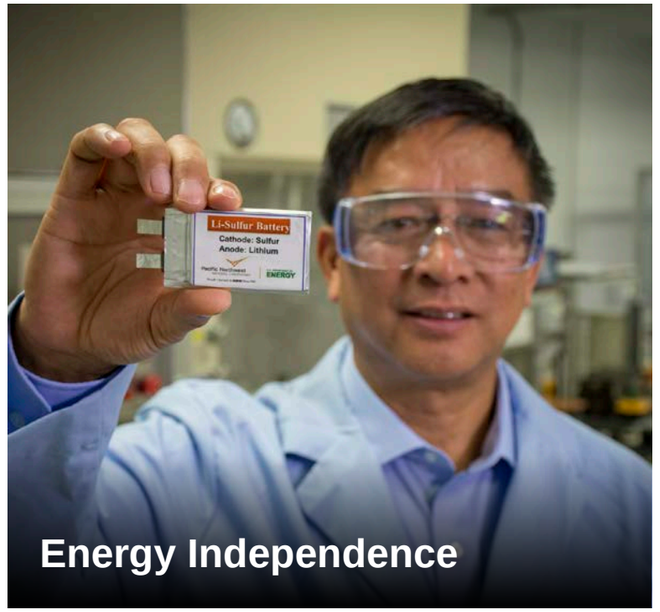

Energy Independence


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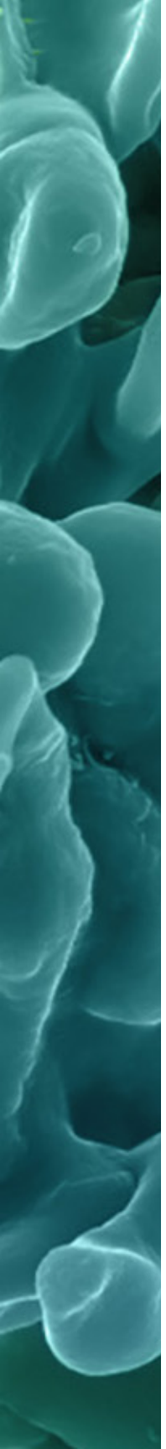

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PNNL is an
ECONOMIC ENGINE

4,722
Employees

265
Inventions

$1.46B
Total Economic Output

$1.01B
Annual Spending

88
Patents

7,180
Jobs Generated
in Washington

$465M
Total Payroll

34
Licenses

193
Companies
with PNNL Roots

Pacific Northwest
NATIONAL LABORATORY

50+ Years

Developing Goodwill

Decades	**$28.5M**	**347,000**	**>120**
FY19	**$0.52M**	**30,000**	**56**
	Philanthropic Investments	Team Battelle Volunteer Hours	Community Organizations

About Me

Alfred University

Bachelor's Degree:
Biomedical Materials Science And Engineering

Pacific Northwest National Laboratory

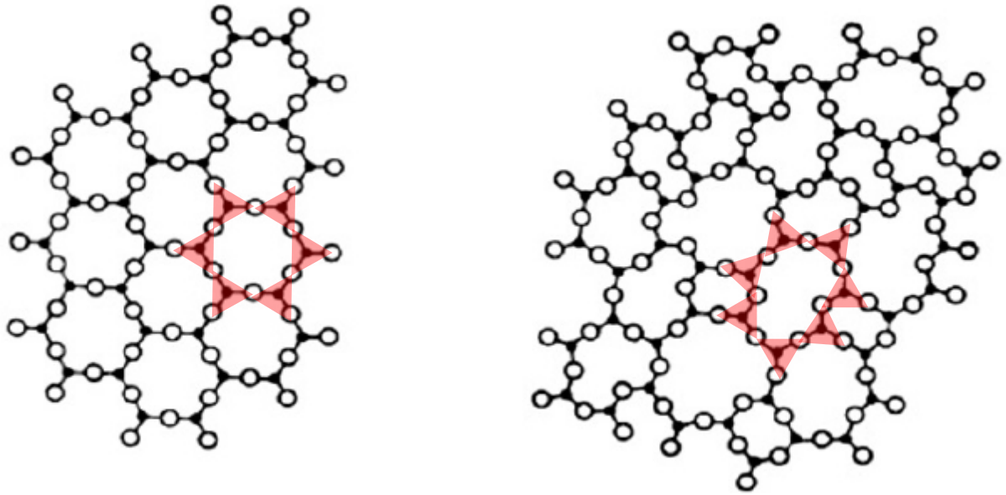
Missouri University of Science and Technology

Started as postdoctoral researcher, transitioned to scientist

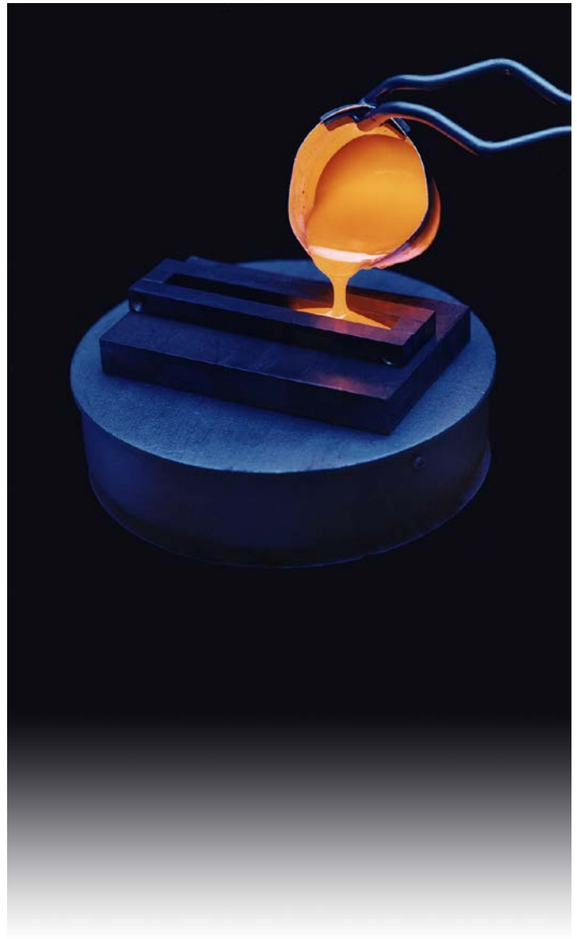
PhD:
Materials Science and Engineering
Thesis:
Dissolution behavior of bio-active borate glasses

What is glass?

- "***Glass is a solid that possesses no long range atomic order and, upon heating, gradually softens to the molten state.***"
  - Non-crystalline structure; amorphous
  - Glass-transition behavior

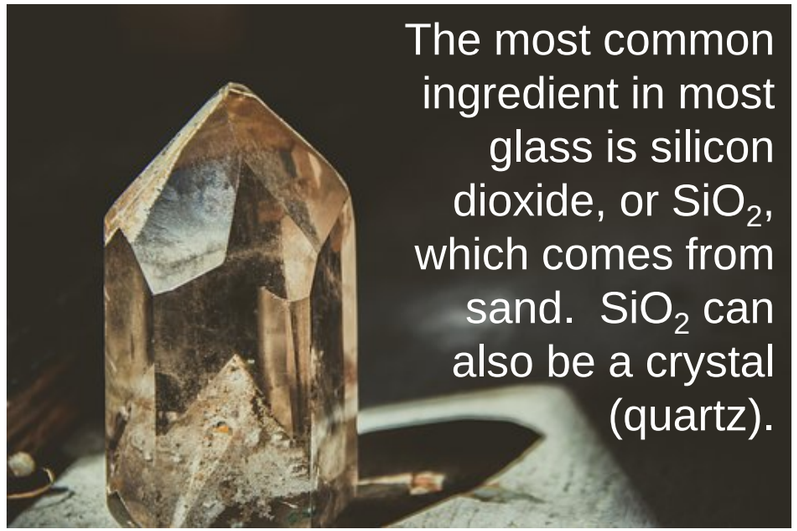


Same polyhedral, different configurations



What is glass made out of?

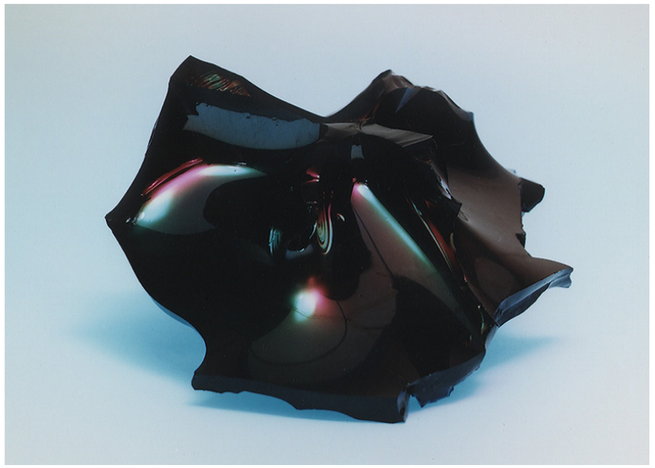
- **Glass forming oxides-** a dominant constituent
  - SiO_2, B_2O_3, P_2O_5
- **Fluxes-** reduce melting temperatures
  - Na_2O, K_2O, PbO, etc.
- **Property modifiers-** added to tailor properties
  - CaO, Al_2O_3, etc.
- **Colorants-** minor constituent
  - Transition metals, rare earth metals
- **Fining agents-** minor constituent to help remove bubbles from melts
- **Cullet**- recycled glass reduces melt time and energy in commercial melters
  - Typically 20-100% of batch



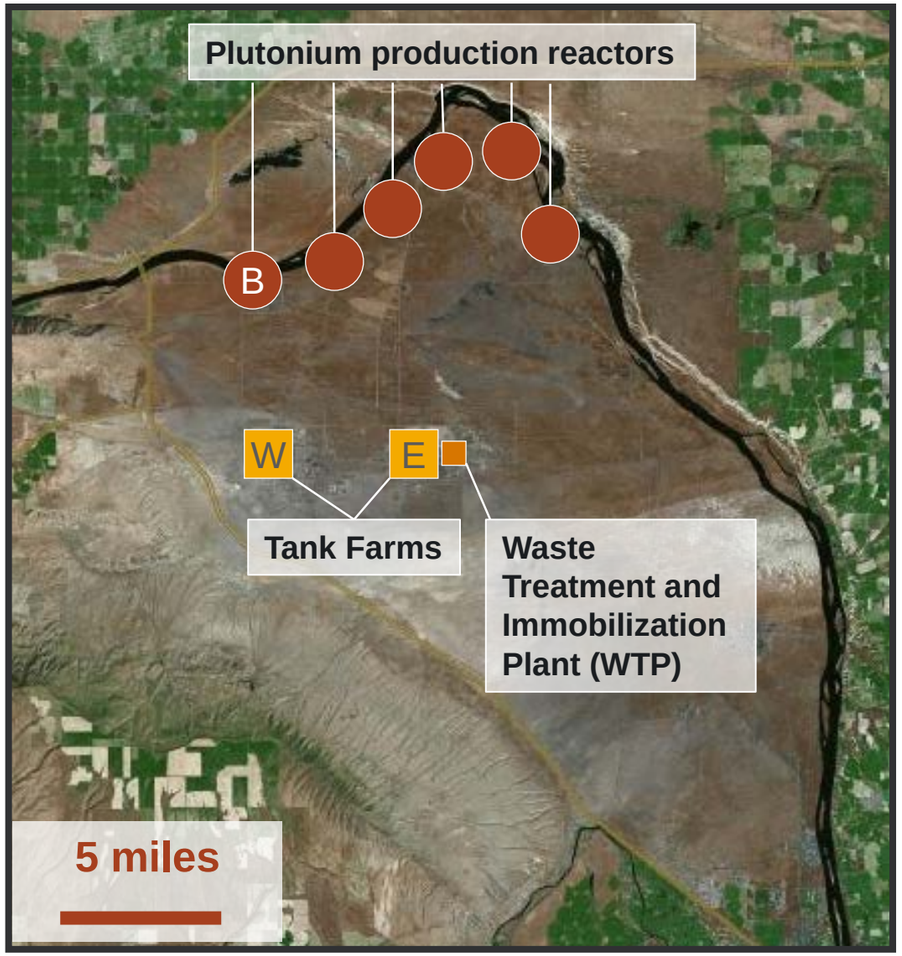
The most common ingredient in most glass is silicon dioxide, or SiO_2, which comes from sand. SiO_2 can also be a crystal (quartz).

“Glass” is a whole family of materials!

- Each type of glass has its own **composition** (what the glass is made of) which control the glass’s **properties** (how the glass behaves).
- Scientists can change the ingredients in glass to change the glass’ properties.
- New materials with better properties are made everyday!
  - Window glass is different from the glass in cell phone screens or the glass in light bulbs!
  - Just because the glass is all clear and transparent doesn’t mean it doesn’t have very different properties!



Hanford Site: Waste will be vitrified at the Waste Treatment and Immobilization Plant (WTP)



Waste will be treated as two different streams:

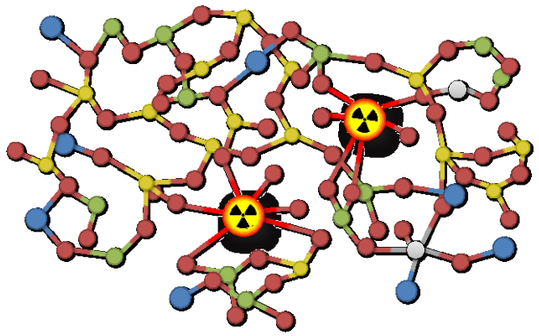
- LAW: Low-activity waste
- HLW: High-level waste

What is vitrification?

"Glass: A Common Material Solving An Uncommon Problem – How Do We Immobilize Nuclear Waste?"

- Immobilization: The process of fixing something into place
  - The solid and liquid nuclear waste in the Hanford tanks is to be immobilized so that it can't travel where it isn't desired

- Vitrification: The process of converting a material into glass
  - The Hanford tank waste won't be stored in glass, it will actually become a glass



⊘ Waste in glass is **not** similar to root beer in a bottle

✓ Waste in glass **is** similar to what makes the bottle brown

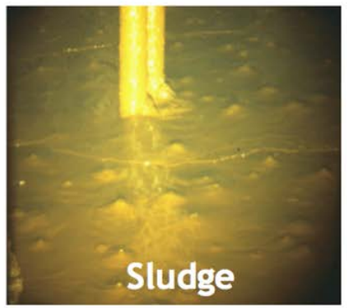
Why use glass for waste immobilization?

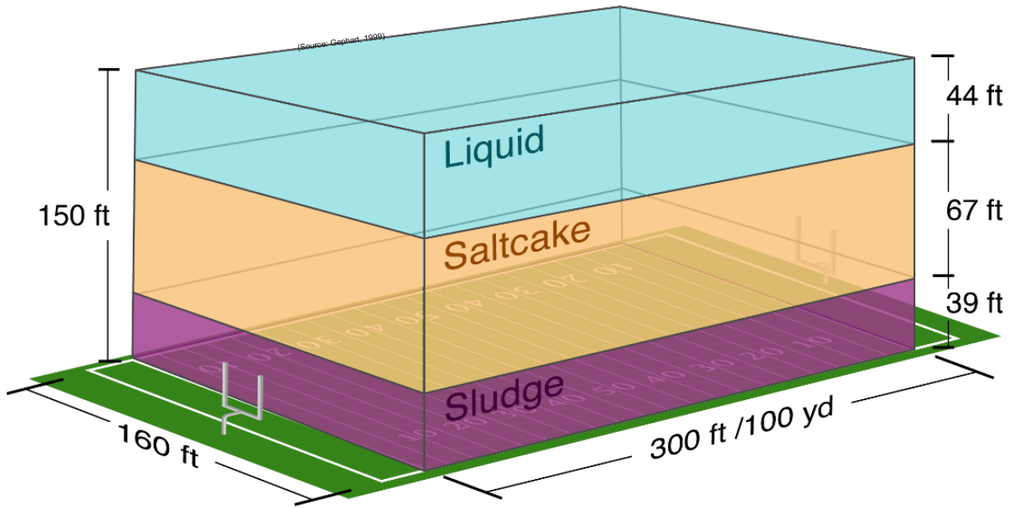
- It is **durable** – It won't degrade in water.
  - Think of your house or car windows, cups and glass containers, and phone screens: how do they respond when they get wet?
- It can be made in **large quantities** – Glass melting technology is mature.
  - Due to the many uses for glass, it is well known how to prepare it (temperatures of around 2100 °F, over 4x as hot as an oven!).
- It is **versatile** – Almost every element can be incorporated into glass.

Tank waste


Salt Supernate


Saltcake

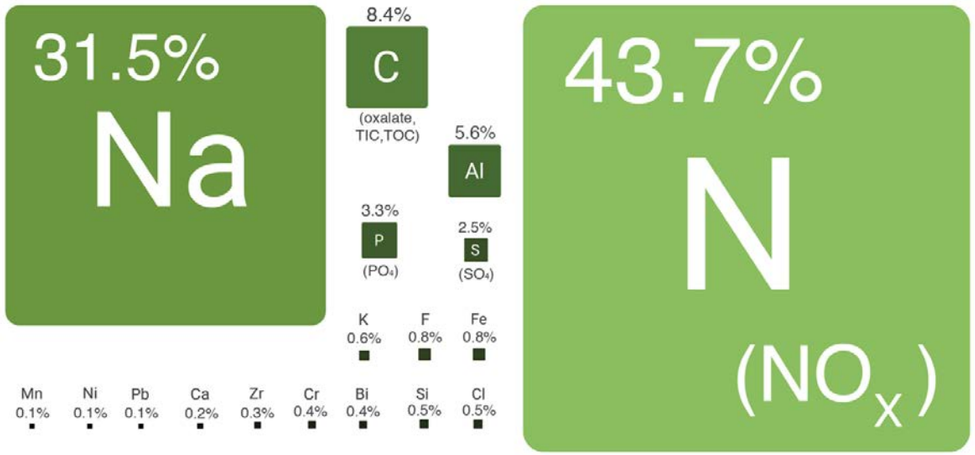

Sludge


Liquid
Saltcake
Sludge
150 ft
44 ft
67 ft
39 ft
160 ft
300 ft /100 yd

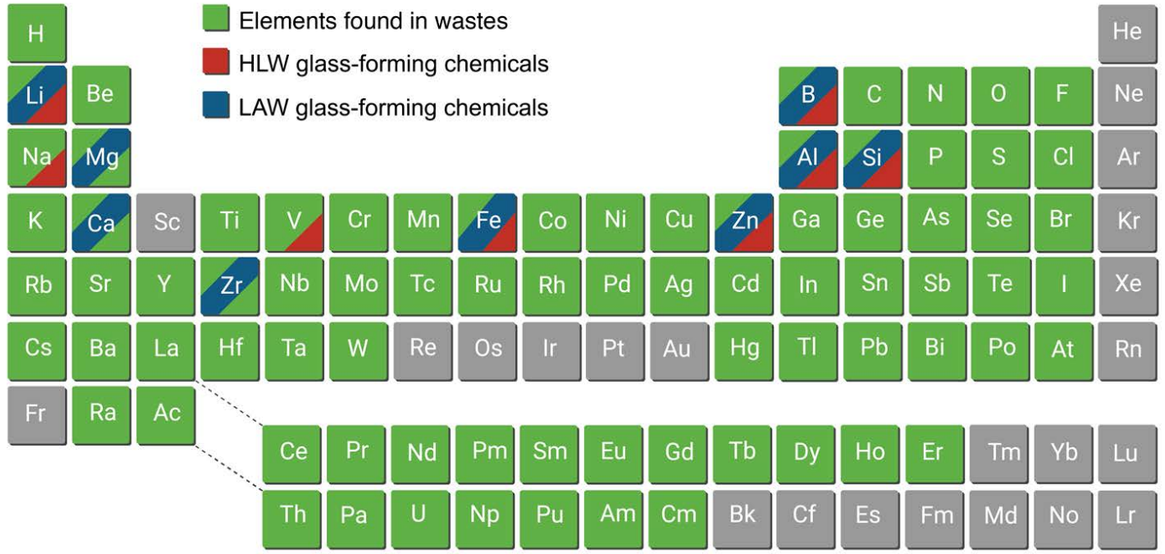
What's in the waste?


Crystallized saltcake in single-shell tank 105-B

Waste is primarily sodium nitrates and other salts…



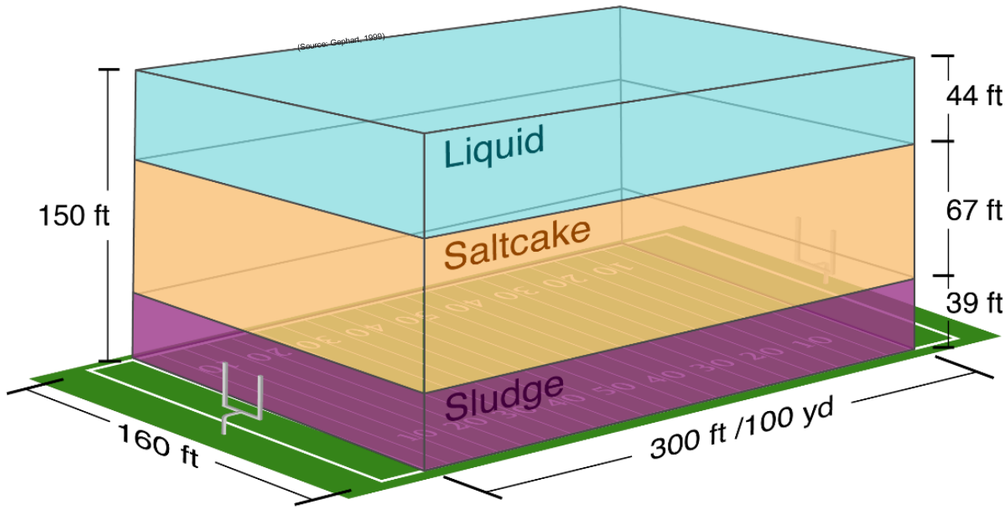
… but most of the periodic table can be found in the waste



Waste treatment

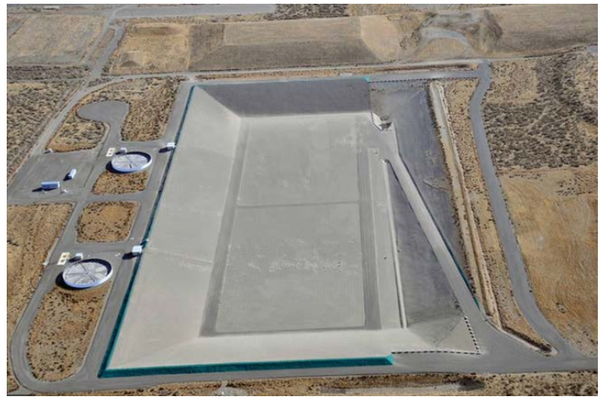
- Waste from tanks will be separated as two different streams
  - LAW: Low-activity waste (about 90% of waste volume)
  - HLW: High-level waste

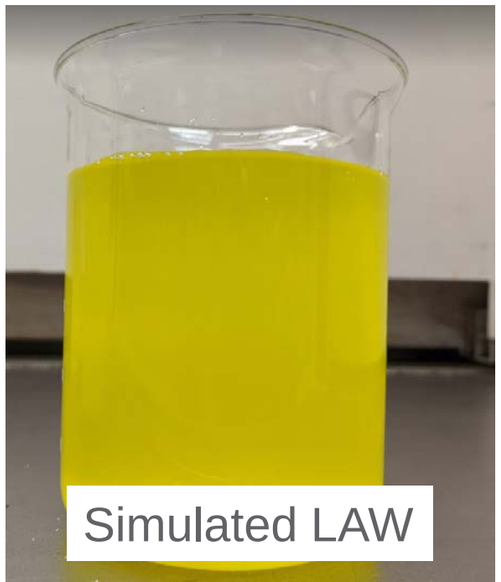
- Filtration separates the liquid from the sludge
  - Sludge is HLW, liquid is LAW
- Ion exchange removes Cs from liquid
  - Cs goes to HLW



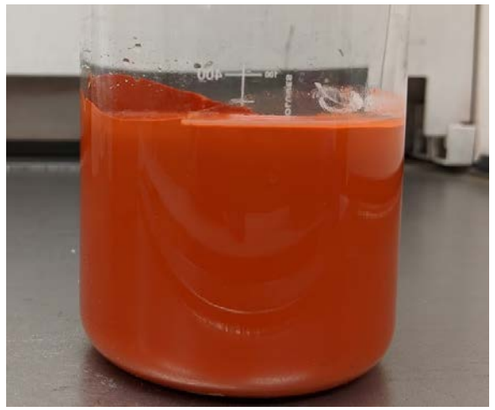
How does vitrification work?

- Waste is mixed with glass-forming chemicals (GFCs) to form a slurry feed, then melted in a joule-heated melter



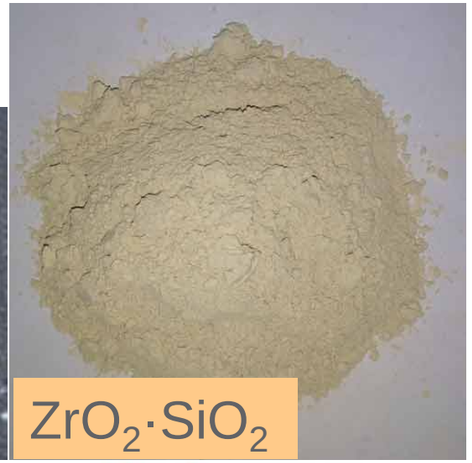


Simulated LAW Slurry Feed



Joule-heated melter uses electrodes to heat glass to 1150 °C

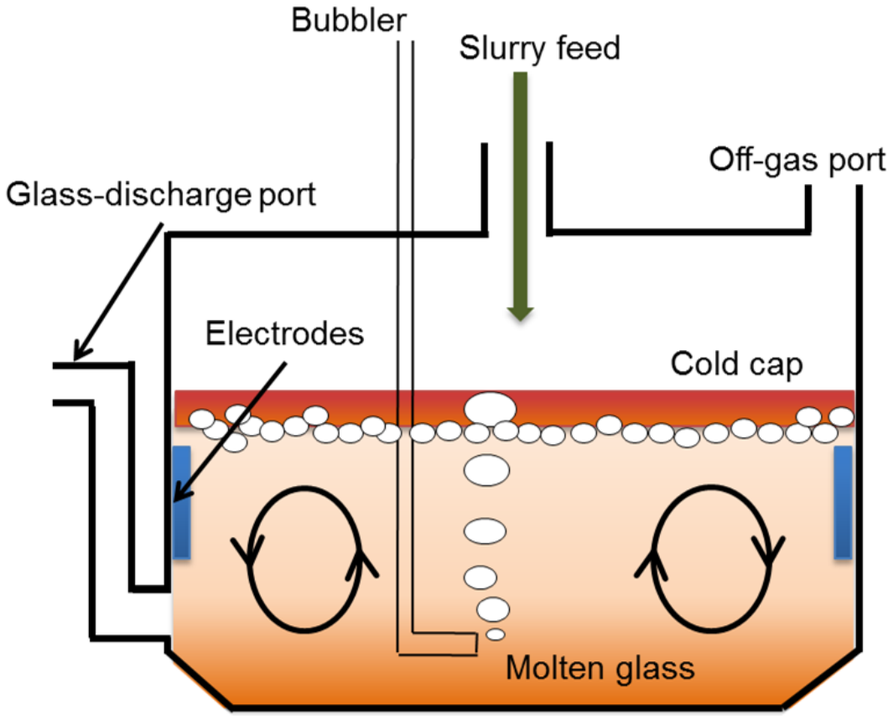
Preparing slurry feeds



Simulated LAW + Glass Forming Chemicals = Slurry Feed

What is a glass melter?

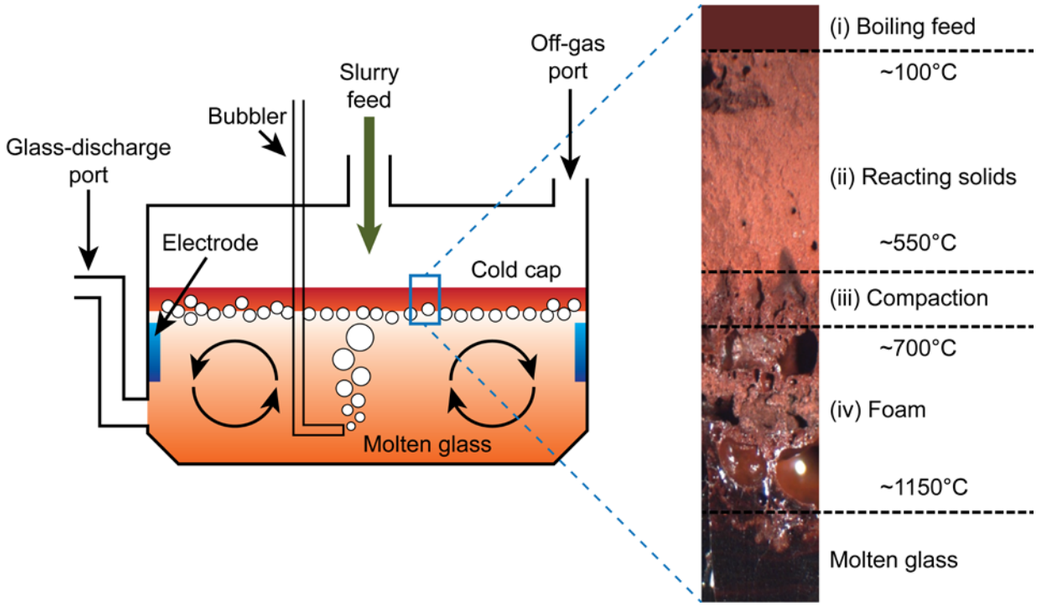
- The LAW melters and HLW melters have different design specifics, but the general design methods to keep the melters in operation are discussed here.



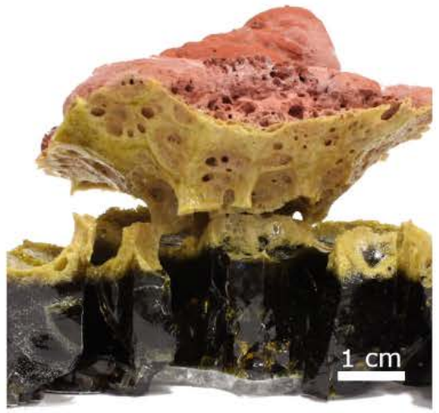
Refractory: Solid, brick-like material that lines the melter, in contact with the glass melt at elevated temperatures.

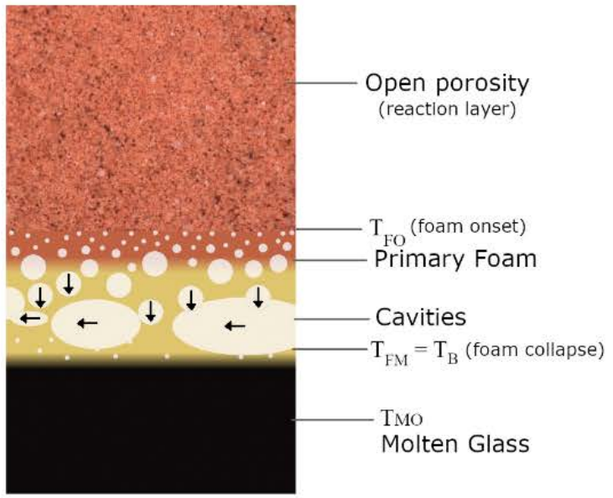
Electrodes: Metal bars for glass heating that must be placed through the refractory.

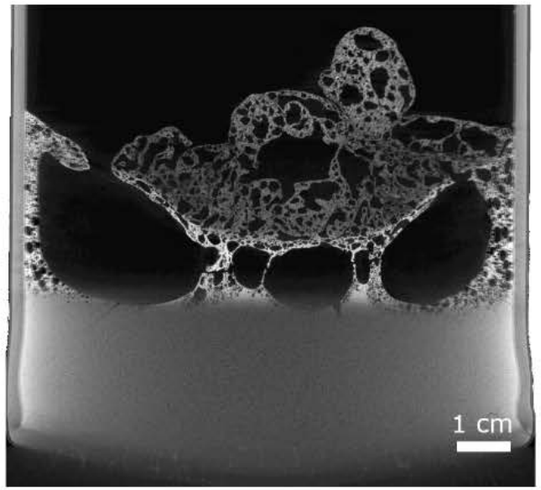
Slurry forms a cold cap on top of the melt as it reacts



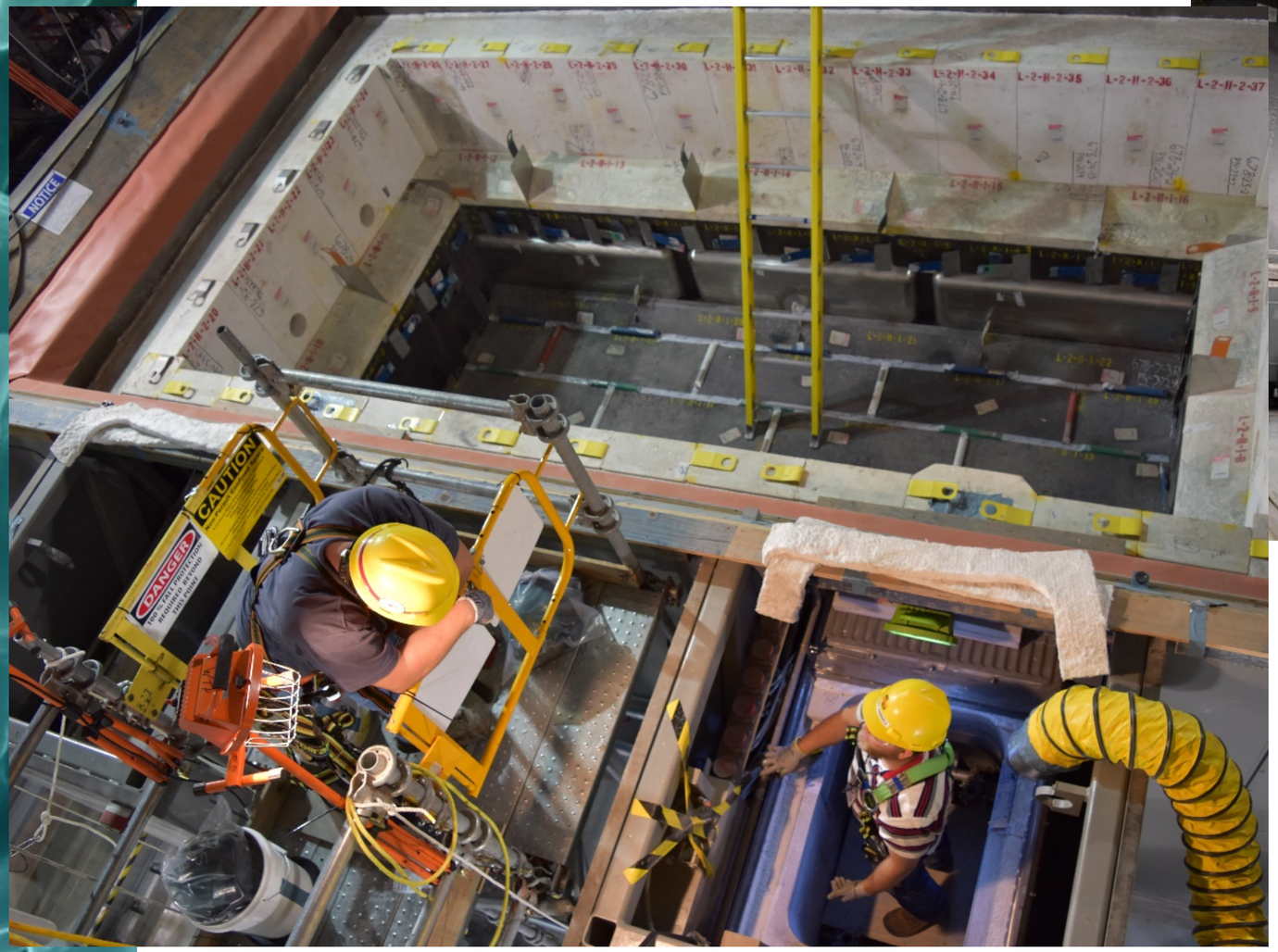
- When slurry is fed onto molten glass, it forms a cold cap
- Water from the slurry begins to boil
- Gases are released as chemicals react, leading to foam and bubbles
- As the reacting feed gets hotter, it begins to melt into the glass

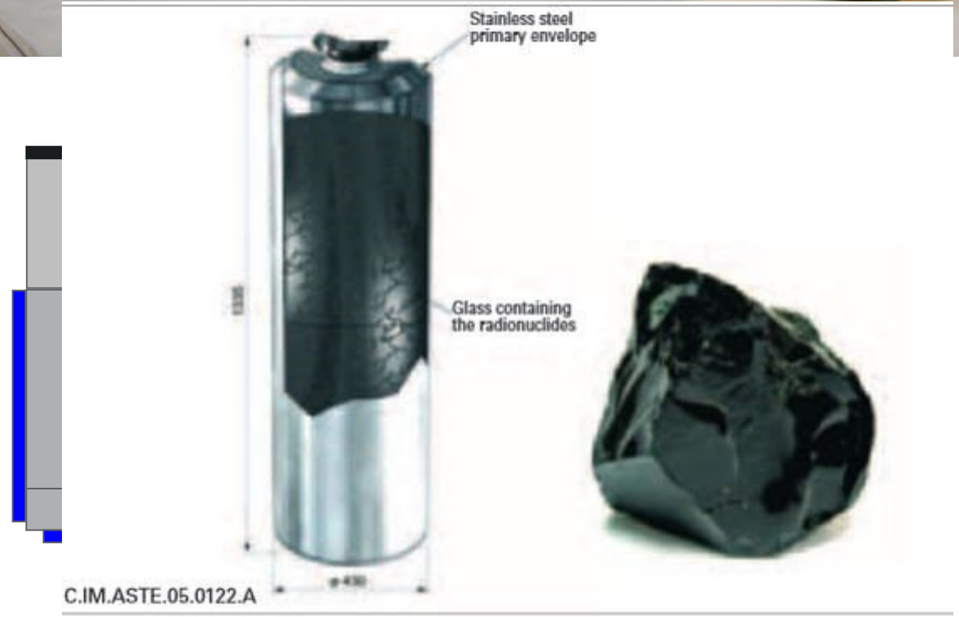






LAW Melters


NOTICE
CAUTION
DANGER


Stainless steel
primary envelope
Glass containing
the radionuclides
C.IM.ASTE.05.0122.A

How do we process glass faster?

How much waste can be processed in a given time period?

- Higher waste throughput means shorter mission

How fast does the given glass composition melt?

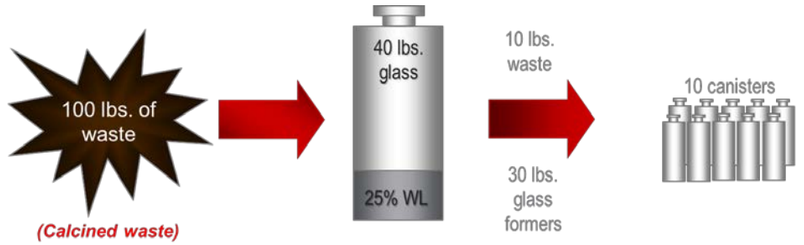
- High-silica/zirconia compositions generally melt slower
- Higher alkali generally melt faster

What ratio of waste to glass forming chemicals is used in the composition?

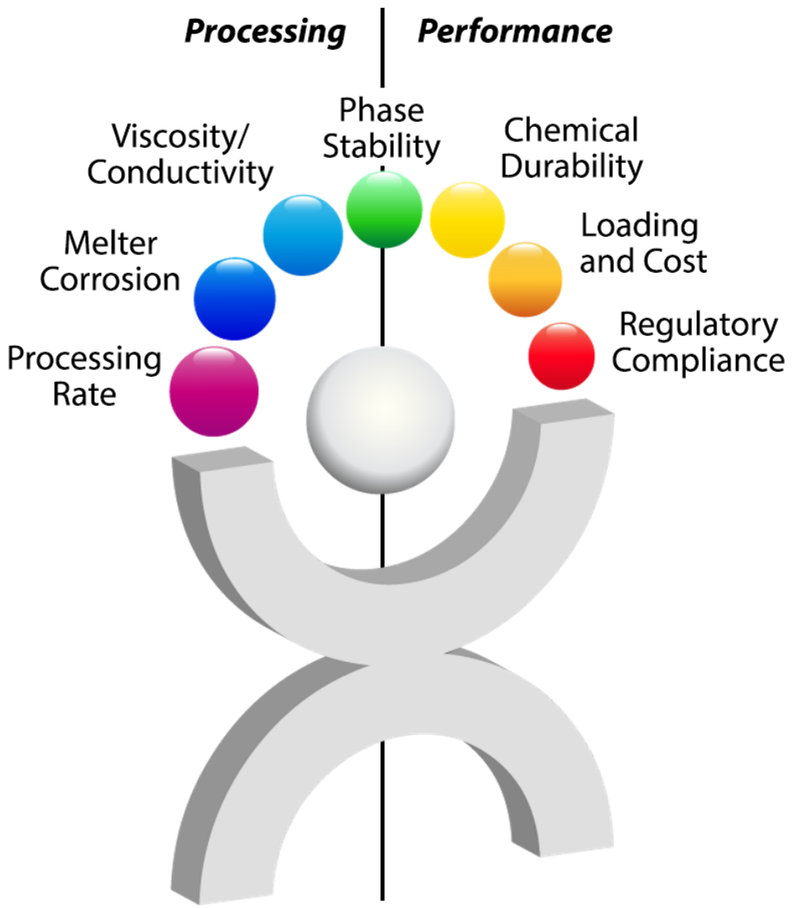
- Higher waste loading means less glass is made because there's a higher percentage of waste components incorporated into the glass

Does this composition lead to other problems?

- Increased corrosion which may lower melter lifetime
- If the melter needs to be shut down, waste throughput is zero!



Things to consider when studying vitrification



- As glass scientists, we make glass and study the properties to help the Waste Treatment and Immobilization Plant run smoothly. Some things scientists do are:
  - Design new glass compositions to increase waste loading
  - Measure properties like viscosity (how easily the glass flows) or chemical durability (how fast the glass degrades)
  - Study how a new glass melts
  - Investigate how fast the glass will corrode the melter
  - Predict problems that might happen during melting glass at the plant and come up with solutions

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Upcoming Seminars

Soils Are Alive!

Aditi Sengupta
Tuesday, June 9
7:00 pm

Hacking Biology to Produce Energy and Fuels

Joseph Laureanti
Tuesday, June 16
7:00 pm

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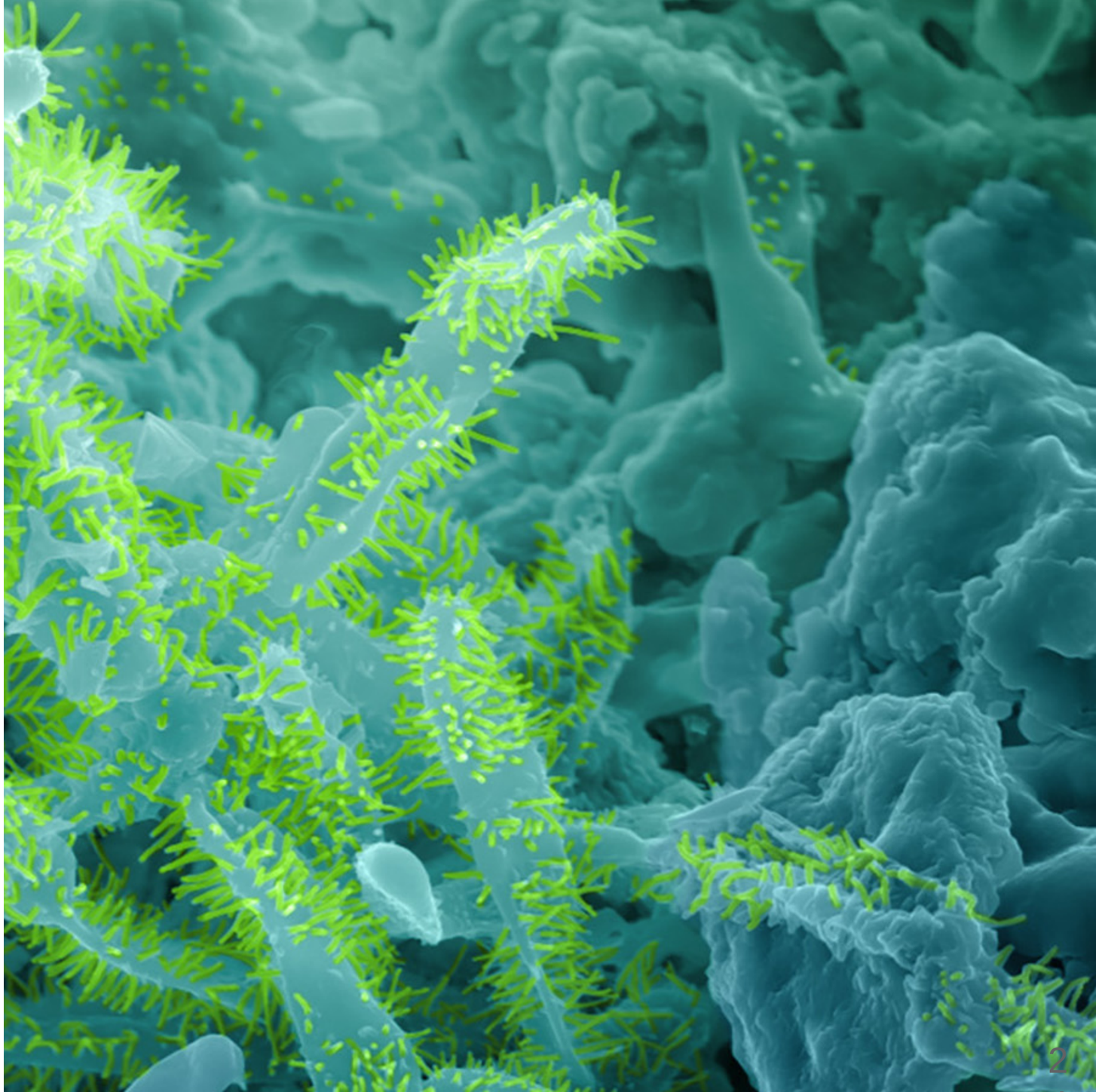
Jaime George
Materials Scientist
WASTEFORM DEVELOPMENT

Phone: (509) 371-6380
jaime.george@pnnl.gov

902 Battelle Boulevard
P.O. Box 999, MSIN K6-28
Richland, WA 99352
www.pnnl.gov



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