



OKAYAMA
UNIVERSITY

Environmental Amorphous Materials Science Group: from basic research to SDGs* oriented-applications

■ Nanba & Benino Group

Graduate School of Environmental & Life Science,
Faculty of Engineering,
Okayama University

● Topics in 2022

On May 18, 2021, the United Nations General Assembly approved a resolution declaring the year 2022 as :

The International Year of Glass

to celebrate the heritage and importance of this material in our lives.

 <https://www.iyog2022.org/>

* SDGs: Sustainable Development Goals – UNESCO - 2015



Glass and SDG global goals.



for deeper understanding of the relation between glass and the SDGs

 <https://www.youtube.com/watch?v=eXpbt5U3OzA>



We are the glassmen!

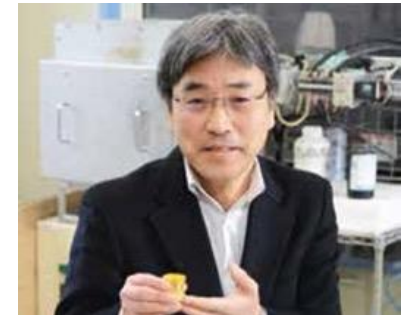
■ *Let's be glassmen, all of us.*

Glass has long been widely used for windows and cups.

Glass properties are also commonly used to solve environmental issues.

We contribute to SDGs achievements by developing very efficient functional glass and ceramic materials

Novel waste-recycling methods and glass-solidification methods of radioactive wastes are investigated.



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On going projects

■ Basic Science

- Relation between structure and properties of glass
- Glass structure analyses by experiments and computer simulations
 - ◆ Experiments: X-ray and Neutron diffraction, XPS, Raman/IR, NMR
 - ◆ Simulations: Molecular orbital (MO), Band calculation, Molecular dynamics (MD), **Reverse Monte Carlo (RMC)**
 - ◆ Glasses: $\text{SnO-P}_2\text{O}_5$, $\text{Bi}_2\text{O}_3\text{-B}_2\text{O}_3$, **$\text{PbO-B}_2\text{O}_3$** , Mo-containing borosilicates and phosphates, anisotropic meta-phosphates

■ Applied Science

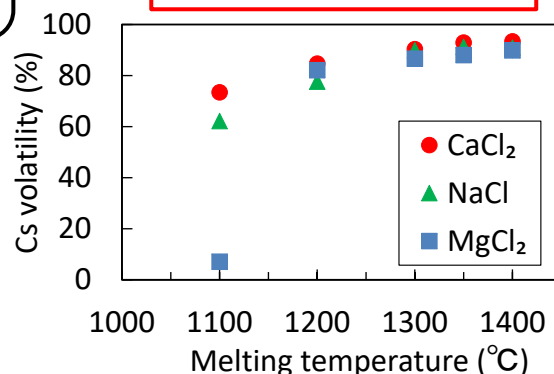
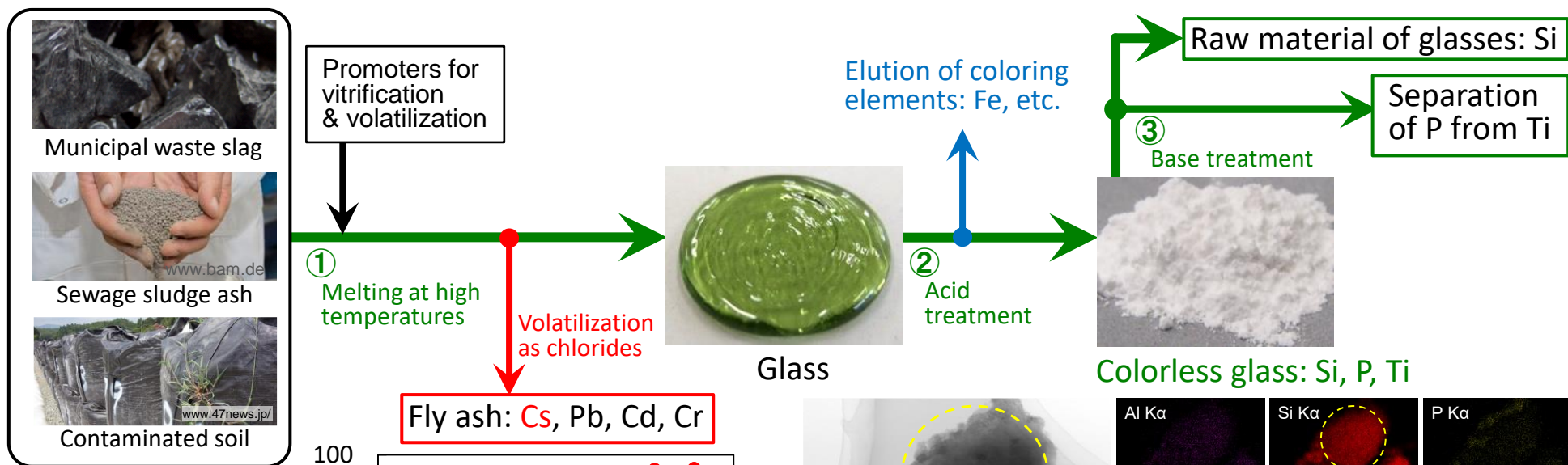
- Pb-free glass: SnO-based phosphate glass for white phosphor
- Waste treatment and related subjects
 - ◆ Chemical recycling process:
Recovery of Si, P, and Ti from municipal waste slag, steel making slag, and sewage sludge ash
 - ◆ Removal process: Radioactive Cs and heavy metals of Pb, Cd, Cr from soils
 - ◆ Glasses for solidification of nuclear wastes: $\text{PbO-ZnO-B}_2\text{O}_3$ glass for Iodine-129 immobilization

👉 Our focused projects: ●, ◆

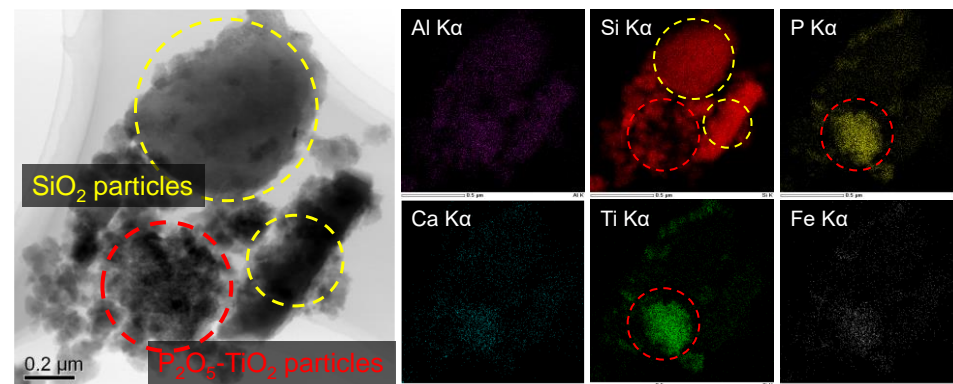
Focused projects

■ Novel waste treatment processes

- Recovery of valuable elements from wastes: Si, P, Ti
- Removal of radioactive and hazardous elements in soils: Cs, Pb, Cd, Cr



Volatility of Cs in a soil vs melting temperature at different chlorination promoters Nakao et al. (2018)



TEM photos of a colorless glass after acid treatment, suggesting different precipitation process of SiO₂ and P-containing TiO₂ particles. Omura et al. (2013)



Focused projects

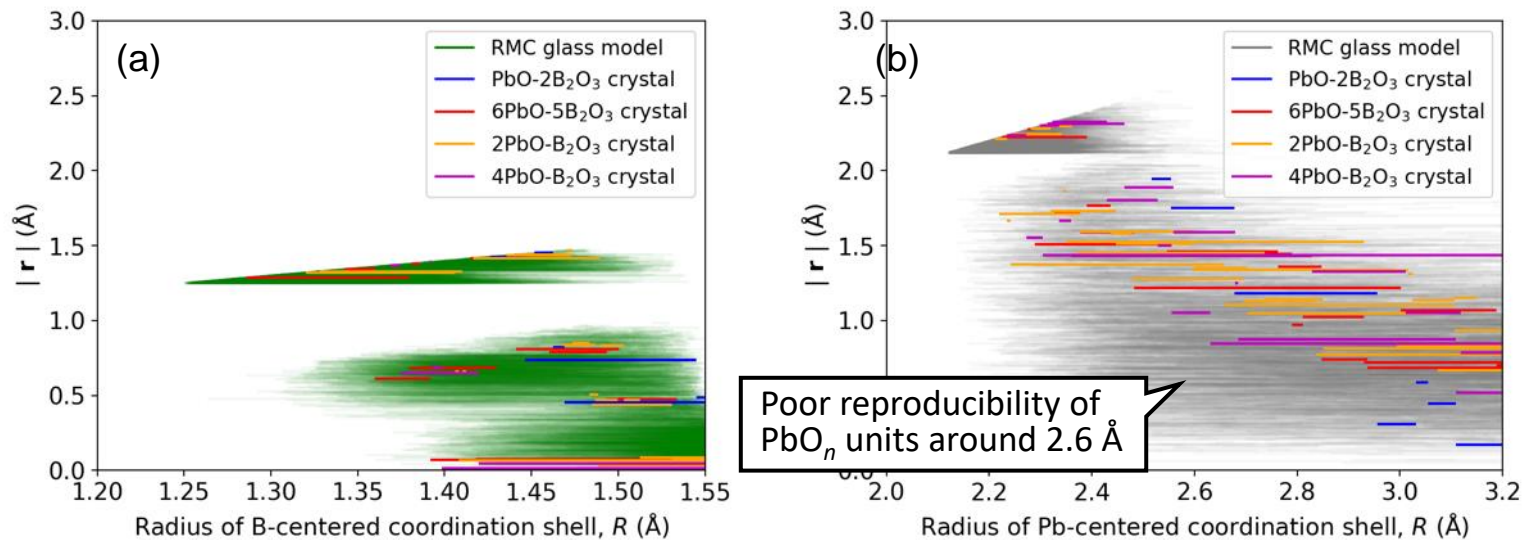
■ Glasses for nuclear waste solidification

- PbO-ZnO-B₂O₃ glass for Iodine-129 immobilization (Half-life of ¹²⁹I: 15.7 million years)
- Structure analysis and chemical stability prediction of glasses by computer simulations
- ◆ Structure modeling of 2PbO-B₂O₃ glass by RMC simulation

Previously reported structure: PbO₃ trigonal pyramid (tp) and PbO₄ trigonal bi-pyramid (tbp)

Difficulty in modeling: Reproduction of asymmetric structures, such as tp and tbp

Limitation of the conventional RMC method:



One of the ligands is lone pair of electrons.

Eccentric distance $|r|$ between the center of gravity of oxygen atoms, U_{CG} and (a) B or (b) Pb [Nagao et al. \(2022\)](#)

Challenge: New RMC calculation option based on AI evaluation of configuration energy



Selected publications

■ Development of novel waste treatment processes

- T. Nanba, S. Mikami, T. Imaoka, S. Sakida, Y. Miura, Chemical recycling of inorganic wastes by using phase separation of glass, *J. Ceram. Soc. Japan*, 116(2) (2008) 220-223, [doi:10.2109/jcersj2.116.220](https://doi.org/10.2109/jcersj2.116.220)
- T. Nanba, Y. Kuroda, S. Sakida, Y. Benino, Chemical recycling of municipal waste slag by using phase separation, *J. Ceram. Soc. Japan*, 117(11), (2009) 1195-1198, [doi:10.2109/jcersj2.117.1195](https://doi.org/10.2109/jcersj2.117.1195)
- Y. Benino, Y. Ohtsuki, S. Sakida, T. Nanba, Effect of additives on the distribution of phosphorus associated with phase separation of borosilicate glasses, *J. Ceram. Soc. Japan*, 120 (11), (2012) 490-493, [doi:10.2109/jcersj2.120.490](https://doi.org/10.2109/jcersj2.120.490)
- K. Omura, S. Sakida, Y. Benino, T. Nanba, Distribution behavior of inorganic constituents in chemical recycling processes of a municipal waste slag, *J. Asian Ceram. Soc.*, 1 (2013) 108-113, [doi:10.1016/j.jascer.2013.03.003](https://doi.org/10.1016/j.jascer.2013.03.003)

■ Development of glasses for nuclear wastes solidification

- A. Mukunoki, T. Chiba, Y. Suzuki, K. Yamaguchi, T. Sakuragi, T. Nanba, Further Development of Iodine Immobilization Technique by Low Temperature Vitrification With BiPbO₂I, ASME 2009 12th International Conference on Environmental Remediation and Radioactive Waste Management, ICEM2009-16268, 329-334, [doi:10.1115/ICEM2009-16268](https://doi.org/10.1115/ICEM2009-16268)
- A. Mukunoki, T. Chiba, Y. Benino, T. Sakuragi, Microscopic structural analysis of lead borate-based glass, *Progress in Nuclear Energy*, 91, (2016) 339–344, [doi:10.1016/j.pnucene.2016.05.008](https://doi.org/10.1016/j.pnucene.2016.05.008)
- M. Nagao, S. Sakida, Y. Benino, T. Nanba, A. Mukunoki, T. Chiba, T. Kikuchi, T. Sakuragi, H. Owada, Effect of bond valence sum on the structural modeling of lead borate glass, *J. Non-Cryst. Solids*, (2022) in press, [doi:10.1016/j.jnoncrsol.2022.121751](https://doi.org/10.1016/j.jnoncrsol.2022.121751)

■ IYOG2022

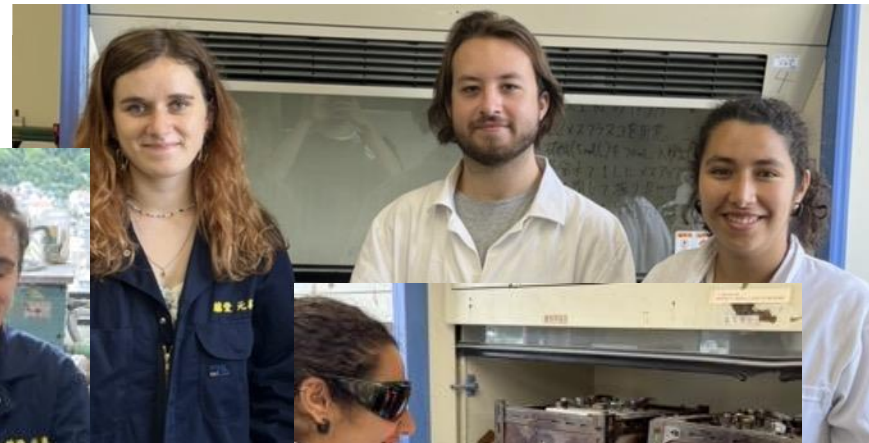
- T. Nanba, Y. Benino, T. Akai, Environmental activities on glass in Japan, *J. Ceram. Soc. Japan*, (2022) in press.



International students from Europe

■ Internship program

- 2017: -1 -Pierre and Marie Curie University 2017
- 2018: - 1 – UPMC - Paris,
- 2 - University of Poitiers
- 2019: - 1 -Sorbonne University,
- 2 -University of Poitiers
- 2022: - 1 – INP Toulouse,
- 2 – INP - Grenoble,
- 3 - University of Turin



2022

International students from Europe



Trip to Kyoto, 2017

International students from Europe



Osaka, 2019

<https://www.facebook.com/okadaicamics>



Trip to Onsen, 2018