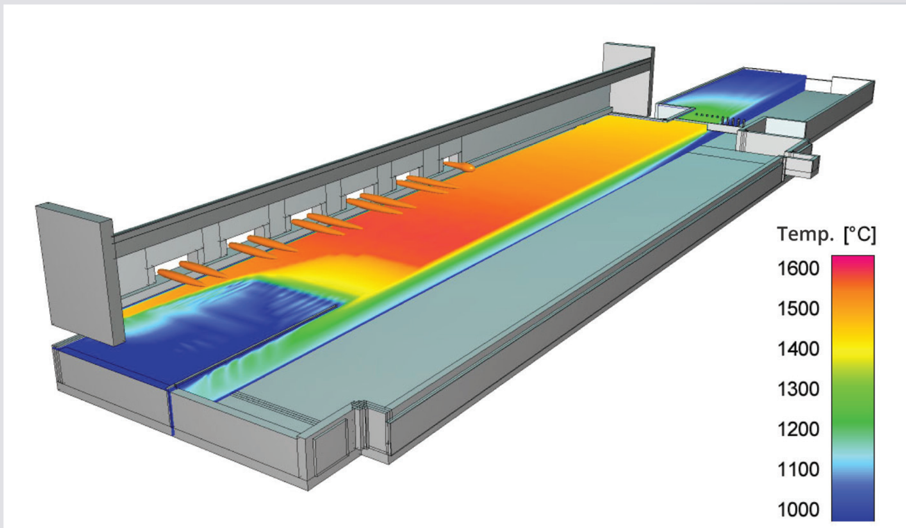
INSTITUTE OF ROCK STRUCTURE AND MECHANICS
The Czech Academy of Sciences

LABORATORY OF INORGANIC MATERIALS

THEMATIC RESEARCH FOCUS

- MELTING PROCESSES AND THEIR MODELLING
- CHEMICAL REACTIONS DURING GLASS MELTING
- THE DEVELOPMENT OF NEW TYPES OF GLASSES
- MATERIALS FOR PHOTONICS AND OPTOELECTRONICS



Temperature distribution in the melting space on the top melt level

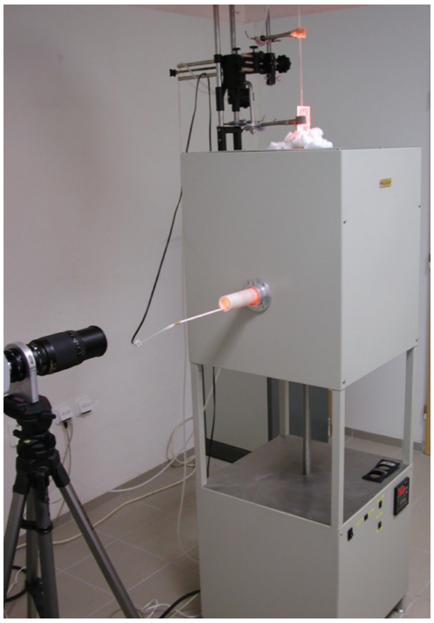
MAIN SCOPE OF RESEARCH

The Laboratory of Inorganic Materials is the successor of the Laboratory of Chemistry and Technology of Silicates of the Czechoslovak Academy of Sciences and Institute of Chemical Technology, Prague, founded in 1961. In 2012, the laboratory was transformed into a joint workplace of the University of Chemistry and Technology, Prague and the Institute of Rock Structure and Mechanics of the Czech Academy of Sciences.

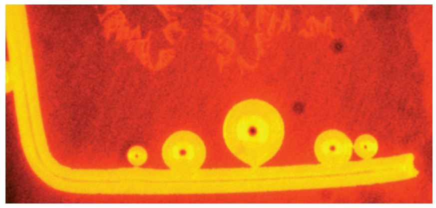
- Mathematical modelling using a Computational Fluid Dynamics (CFD) simulation to calculate velocity and temperature distribution in a melting space.
- Quantitative evaluation of the main melting processes in a continuous melting space.
- Optimization of the glass melting process by influencing the chemical reaction of sulphur compounds.
- Observation of bubble nucleation in glass melts.
- Description of bubble behaviour in a viscous fluid under the action of a centrifugal force.
- Development of new types of glasses, eliminating heavy metal oxides, particularly lead and barium.
- Research of vitrification processes to immobilise nuclear waste.
- Corrosion tests of refractories by molten glasses.
- Research and development of special glasses for photonics.

KEY RESEARCH EQUIPMENT

- Preparation of glasses under defined conditions.
- Visual observation and image analysis processes in glass melts.
- Determination of the solubility of gases in glass melts (GC-MS).
- Evolved gas analysis (EGA).
- Determination of oxygen partial pressure in glass melts.
- Thermal analysis (DTA / TG / DSC).
- Polarization microscopy.
- Measurement of glass transmission in the UV / VIS and IR regions.
- Feed volume expansion test.



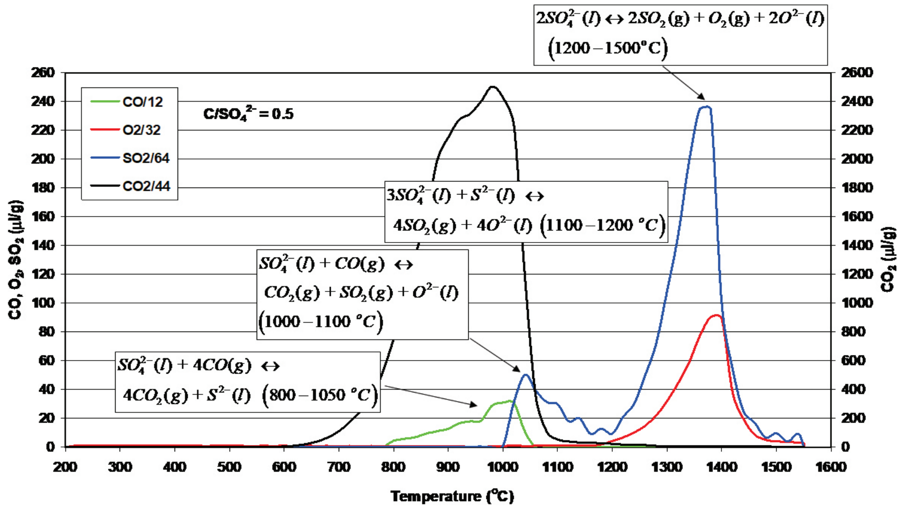
High temperature observation furnace



Nucleation of bubbles on a platinum wire immersed in a glass melt

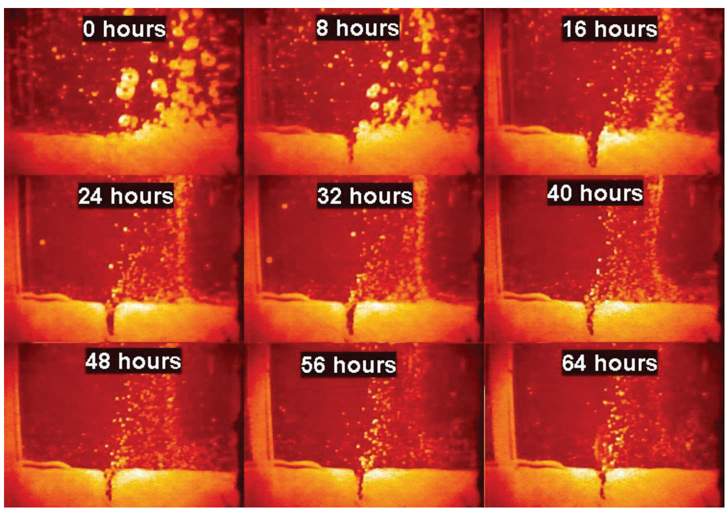
Using image analysis to measure bubble size

Static plate corrosion test – crucible with refractory material corroded by glass melt



Analysis of gases (EGA) evolved from a glass batch containing sodium sulphate and carbon

Laboratory furnaces for glass preparation



Identification of bubble sources during glass melting

ACHIEVEMENTS

Vitrification of nuclear waste

Marcial J., Pokorný R., Kloužek J., Vernerová M., Lee S., Hrma P., Kruger A. (2021). *Effect of water vapour and thermal history on nuclear waste feed conversion to glass*. International Journal of Applied Glass Science, 12, 145–157.

doi: 10.1111/ijag.15803

Lee S., Ferkl P., Pokorny R., Klouzek J., Hrma P., Eaton W., Kruger A. (2020). *Simplified melting rate correlation for radioactive waste vitrification in electric furnaces*. Journal of the American Ceramic Society 103, 5573–5578.

doi: 10.1111/jace.17281

Pokorny R., Hrma P., Lee S., Klouzek J., Choudhary M., Kruger A. (2020). *Modelling batch melting: Roles of heat transfer and reaction kinetics*. Journal of the American Ceramic Society 103, 701–718.

doi: 10.1111/jace.16898

Guillen D.P., Lee S., Hrma P., Traverso J., Pokorny R., Klouzek J., Kruger A.A. (2020). *Evolution of chromium, manganese and iron oxidation state during conversion of nuclear waste melter feed to molten glass*. Journal of Non-Crystalline Solids 531, 119860.

doi: 10.1016/j.jnoncrysol.2019.119860

Lee S.M., Hrma P., Pokorny R., Traverso J.J., Klouzek J., Schweiger M.J., Kruger A.A. (2019). *Heat transfer from glass melt to cold cap: effect of heating rate*. International Journal of Applied Glass Science 10, 401–413.

doi: 10.1111/ijag.13104

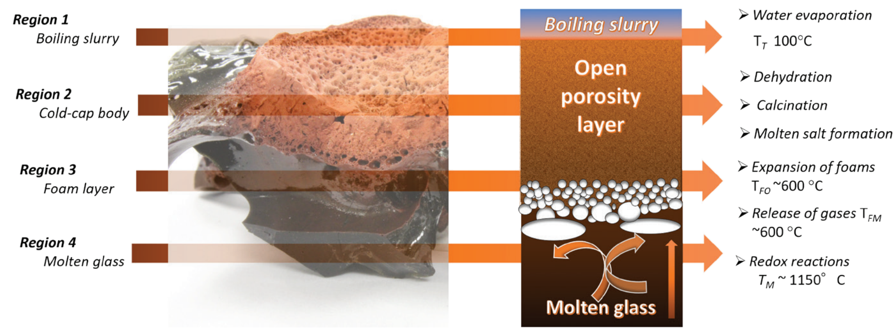
Appel C.J., Klouzek J., Jani N., Lee S.M., Dixon D.R., Hrma P., Pokorny R., Schweiger M.J., Kruger A.A. (2019). *Effect of sucrose on foaming and melting behavior of a low-activity waste melter feed*. Journal of the American Ceramic Society 102, 7594–7605.

doi: 10.1111/jace.16675

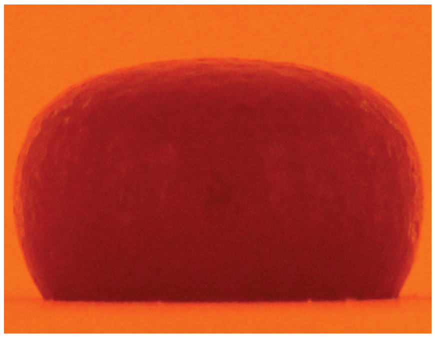
Hrma P., Klouzek J., Pokorny R., Lee S.M., Kruger A.A. (2019). *Heat transfer from glass melt to cold cap: Gas evolution and foaming*. Journal of the American Ceramic Society, 102, 5853–5865.

doi: 10.1111/jace.16484

Lee S.M., Hrma P., Pokorný R., Kloužek J., Eaton W., Kruger A.A. (2019). *Glass production rate in electric furnaces for radioactive waste vitrification*. Journal of the American Ceramic Society 102, 5828–5842.
doi: 10.1111/jace.16463



Cold cap – a reacting material floating on the top of molten glass and schematic illustration of a cold cap



Feed volume expansion test (810°C)

Hujová M., Kloužek J., Cutforth D.A., Lee S.M., Miller M.D., McCarthy B., Hrma P., Kruger A.A., Pokorný R. (2019). *Cold-cap formation from a slurry feed during nuclear waste vitrification*. Ceramics International 45, 6405–6412.

doi: 10.1016/j.ceramint.2018.12.127

Hujova M., Pokorny R., Klouzek J., Dixon D.R., Cutforth A., Seungmin Lee, McCarthy B.P., Schweiger M.J., Kruger A.A., Hrma P. (2017): *Determination of Heat Conductivity of Waste Glass Feed and its Applicability for Modeling the Batch-to-Glass Conversion*. Journal of the American Ceramic Society 100, 5096–5106.

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Glass melting processes

Pereira L., Kloužek J., Vernerová M., Laplace A., Pigeonneau F. (2020). *Experimental and numerical investigations of an oxygen single bubble shrinkage in a borosilicate glass-forming liquid doped with cerium oxide*. Journal of the American Ceramic Society 103, 6736–6745.

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Ueda N., Vernerová M., Kloužek J., Ferkl P., Hrma P., Yano T., Pokorný R. (2021). *Conversion kinetics of container glass batch melting*. Journal of the American Ceramic Society 104, 34–44.

doi: 10.1111/jace.17406

Jebavá M., Hrbek L., Němec L. (2019). *Energy distribution and melting efficiency in glass melting channel: Effect of heat losses, average melting temperature and melting kinetics*. Journal of Non-Crystalline Solids 521, 119478.

doi: 10.1016/j.jnoncrysol.2019.119478

Hrbek L., Jebavá M., Němec L. (2018). *Energy distribution and melting efficiency in glass melting channel: Diagram of melt flow types and effect of melt input temperature*. Journal of Non-Crystalline Solids 482, 30–39.

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Vernerová M., Němec L., Kloužek J., Hujová M. (2018). *Gas release phenomena in soda-lime-silica glass*. Journal of Non-Crystalline Solids 500, 158–166.

doi: 10.1016/j.jnoncrysol.2018.07.058

Jebavá M., Němec L. (2018). *Role of glass melt flow in container furnace examined by mathematical modelling*. Ceramics-Silikáty 62, 86–96.

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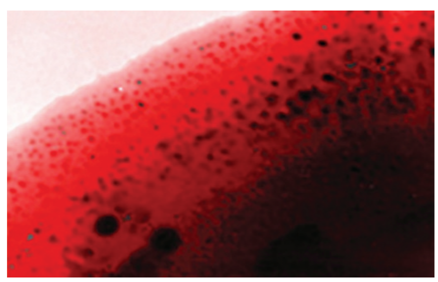
Hrbek L., Kocourková P., Jebavá M., Cincibusová P., Němec L. (2017). *Bubble removal and sand dissolution in an electrically heated glass melting channel with defined melt flow examined by mathematical modelling*. Journal of Non-Crystalline Solids 456, 101–113.
doi: 10.1016/j.jnoncrysol.2016.11.013



TEM micrograph of gold nanoparticles in ruby glass

Cincibusová P., Němec L. (2015). *Mathematical modelling of bubble removal from the glass melting channel with defined melt flow and the relation between the optimal flow conditions of bubble removal and sand dissolution*. Glass Technol.: Eur. of Glass Sci. and Technol. Part A, 56, 52–62

- **Development of new types of glasses**

Kloužek J., Němec L., Tesař J., Hřebíček M., Kaiser K. (2010). *Ruby glass coloured by gold*. Patent No. CZ 302143.

- **Materials for photonics and optoelectronics**

Kostka P., Yatskiv R., Grym J., Zavadil J. (2021). *Luminescence, up-conversion and temperature sensing in Er-doped TeO_2-$PbCl_2$-WO_3 glasses*. Journal of Non-Crystalline Solids 553, 120287.

doi: 10.1016/j.jnoncrysol.2020.120287

Kostka P., Ivanova Z.G., Nouadji M., Černošková E., Zavadil J. (2019). *Er-doped antimonite Sb_2O_3-PbO-ZnO/ZnS glasses studied by low-temperature photoluminescence spectroscopy*. Journal of Alloys and Compounds 700, 866–872.

doi: 10.1016/j.jallcom.2018.11.361

Gedikoglu N., Celikbilek Ersundu M., Kostka P., Bašinová N., Ersundu A.E. (2018). *Investigating the influence of transition metal oxides on temperature dependent optical properties of $PbCl_2$-TeO_2 glasses for their evaluation as transparent large band gap semiconductors*. Journal of Alloys and Compounds 748, 687–693.

doi: 10.1016/j.jallcom.2018.03.209

Sayyed M.I., Celikbilek Ersundu M., Ersundu A.E., Lakshminarayana G., Kostka P. (2018). *Investigation of radiation shielding properties for MeO-$PbCl_2$-TeO_2 (MeO= Bi_2O_3, MoO_3, Sb_2O_3, WO_3, ZnO) glasses*. Radiation Physics and Chemistry 144, 419–425.

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Kostka P., Kabalci I., Tay T., Gladkov P., Zavadil J. (2017). *Investigation of Er doped zinc borate glasses by low-temperature photoluminescence*. Journal of Luminescence 192, 1104–1109.

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Ivanova Z.G., Zavadil J., Kostka P., Djouama T., Reinfelde M. (2017). *Photoluminescence properties of Er-doped Ge–In (Ga)–S glasses modified by caesium halides*. Physica Status Solidi B 254 (6), 1600662.

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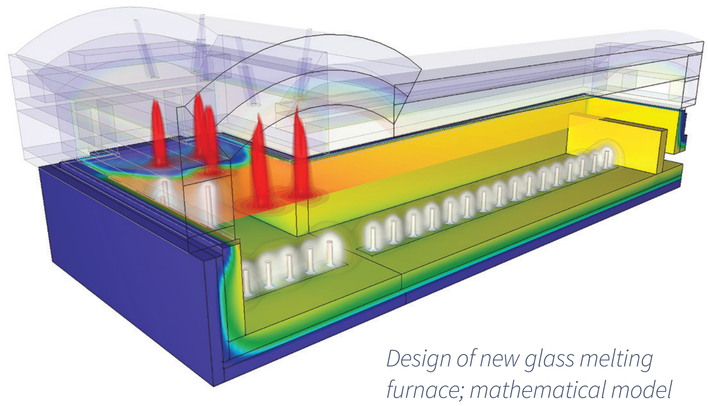

Design of new glass melting furnace; mathematical model

Matějec V., Pedlíková J., Bartoň I., Zavadil J., Kostka P. (2016). *Optical properties of As_2S_3 layers deposited from solutions*. Journal of Non-Crystalline Solids 431, 47–51.

doi: 10.1016/j.jnoncrysol.2015.04.027

Kubliha M., Soltani M.T., Trnovcová V., Legouera M., Labaš V., Kostka P., Le Coq D., Hamzaoui M. (2015). *Electrical, dielectric, and optical properties of Sb_2O_3–Li_2O–MoO_3 glasses*. Journal of Non-Crystalline Solids 428, 42–48.

doi: 10.1016/j.jnoncrysol.2015.07.021

Kostka P., Zavadil J., Iovu M.S., Ivanova Z.G., Furniss D., Seddon A.B. (2015). *Low-temperature photoluminescence in chalcogenide glasses doped with rare-earth ions*. Journal of Alloys and Compounds 648, 237–243.

doi: 10.1016/j.jallcom.2015.05.135

Bošák O., Kostka P., Minárik S., Trnovcová V., Podolinčiaková J., Zavadil J. (2013). *Influence of composition and preparation conditions on some physical properties of TeO_2-Sb_2O_3-$PbCl_2$ glasses*. Journal of Non-Crystalline Solids 377, 74–78.

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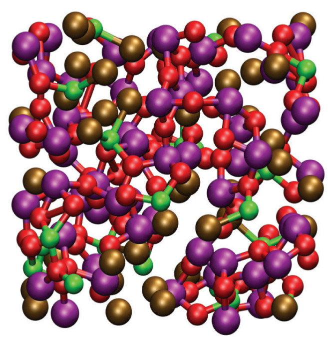

Snapshot of the 3D structure of the $ZnBr_2$-Sb_2O_3 glass modelled using FP MD. Colour legend: Sb (violet), Zn (green), O (red), Br (brown)

MAIN COLLABORATING PARTNERS

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- Pacific Northwest National Laboratory (USA)
- Idaho National Laboratory (USA)
- International Partners in Glass Research (Switzerland)
- Glass Service a.s. (Vsetín, Czech Republic)
- Asahi Glass Co., Ltd. (Japan)
- Slovak Technical University (Slovakia)
- Preciosa a.s. (Czech Republic)
- UMR 6226, Université de Rennes 1 (France)
- Yıldız Technical University, Istanbul (Turkey)
- Karabük University, Karabük (Turkey)
- University of Biskra (Algeria)
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