2025

International Symposium on Liquid Salts Chemistry and Materials Technology

Conference Manual

会议手册

December 18–20,2025

To All Relevant Experts, Scholars and Industries:

Against the backdrop of a global energy transition, ionic liquids and molten salts (collectively, liquid salts) technologies are demonstrating tremendous development potential. Liquid salts are important for thermal, thermochemical and solar energy storage, as coolants / solvents in nuclear reactors, as electrolytes in batteries and for industrial electrochemical reactions, and as media for fuel cells and CO_2 capture. In particular, Thorium Molten Salt Reactor(TMSR), with their revolutionary safety designs and sustainable features, have emerged as the representative of the fourth-generation nuclear energy technologies. Critical breakthroughs in sustainable clean energy are emerging based on liquid salts. In recent years, significant progress has been made in areas, including: molten salt preparation, electrochemical separation, ionic liquids as engineering materials and in systems engineering, creating innovative opportunities in emerging fields within renewable energy storage. To promote the innovative application of liquid salts technologies in clean energy and enhance international academic exchange and collaborations, the Shanghai Institute of Applied Physics (SINAP), Chinese Academy of Sciences, and the Molten Salt and Ionic Liquid Discussion Group (MSILDG) of the Royal Society of Chemistry (RSC) are jointly organizing the “**2025 International Symposium on Liquid Salts Chemistry and Materials Technology**” which will include the “**2025 MSILDG Christmas Research Meeting**”.

Organizers/ 组织机构

Shanghai Institute of Applied Physics, Chinese Academy of Sciences
中国科学院上海应用物理研究所
Molten Salts and Ionic Liquids Discussion Group, Royal Society of Chemistry
英国皇家化学学会熔盐和离子液体讨论小组

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George Zheng Chen	(University of Nottingham, United Kingdom)
Xiangzhou Cai	(Shanghai Institute of Applied Physics, Chinese Academy of Sciences, China)

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Tim Harte	(Deakin University, Australia)

Content

Things You Should Know / 注意事项

Registration / 报到注册

Participants will check in and register in the first-floor lobby of the Sheraton Shanghai Jiading Hotel, located at No. 66 Jiatang Highway, Juyuan New Area, Jiading District, Shanghai, China, and collect conference materials.

参会代表在上海市嘉定区菊园新区嘉唐公路66号上海嘉定喜来登酒店一层大厅报到注册,并领取会议资料。

It is recommended that the presenters contact the conference staff to copy their presentation slides during the conference registration.

建议会议报告人在会议注册时联系会务组录入ppt文件。

Accommodation / 住宿

Please check in at the reception desk.

请在酒店前台办理住宿。

The check-out time is no later than **12:00**. Please note that after **12:00** will be charged for another half-a-day's hotel fee and after **18:00** will be charged for one whole day's hotel fee.

酒店的退房时间为当天**12:00**前，**18:00**前退房加收半天房费，

18:00后退房将收取一天房费。

If you need an accommodation invoice, please get it at the reception desk and carefully check the invoice information before you leave the hotel.

如需发票请在离开酒店时在酒店前台开具，并仔细核对开票信息。

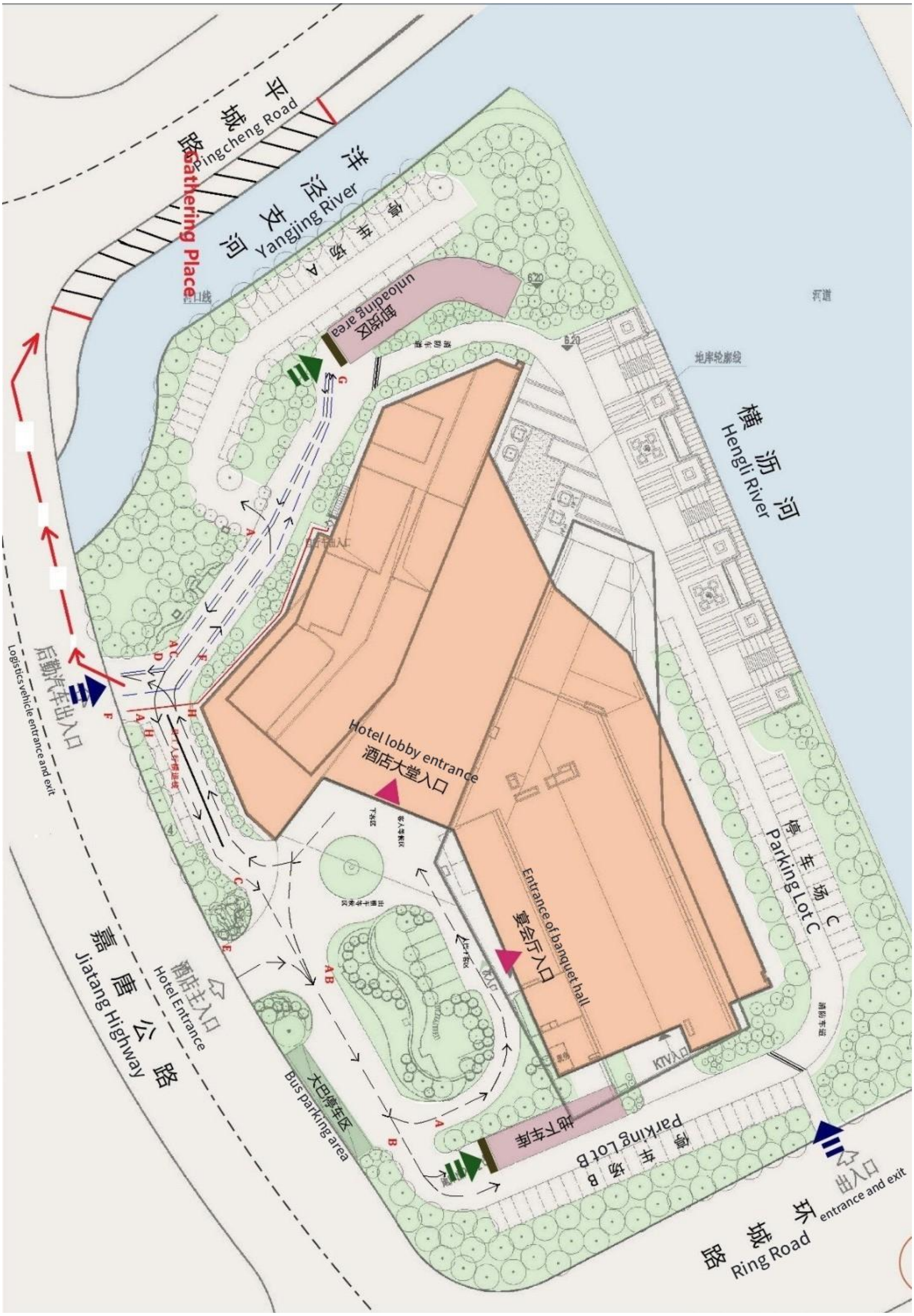
Meals / 用餐

Please have breakfast with your hotel key card and use meal vouchers for buffet and banquet. Meal vouchers are valid on the day of issue and for the specific meal.

早餐凭酒店房卡用餐，午餐、晚餐持会务组所发餐券用餐，餐券当日、当餐有效。

Contact / 联系方式

Xiumei You/游秀梅 +8613693526893 Xu Liu/柳 絮 +8613520861220


平城路
Pingcheng Road
Gathering Place
洋泾支河
Yangjing River
停车场A
卸货区
unloading area
横沥河
Hengli River
地库轮廓线
河道
6.20
后勤汽车出入口
Logistics vehicle entrance and exit
Hotel lobby entrance
酒店大堂入口
Entrance of banquet hall
宴会厅入口
停车场C
Parking Lot C
KTV入口
酒店主入口
Hotel Entrance
嘉唐公路
Jiatang Highway
大巴停车区
Bus parking area
停车场B
Parking Lot B
出入口
entrance and exit
环城路
Ring Road
A
B
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G
H

Conference Program

会议日程

Date 日 期	Time 时 间	Content 内 容	Location 地 点
December 18 12 月 18 日	14:00-21:00	Registration 报到注册	Lobby, 1F 一楼大厅
	11:30-13:30	Buffet 午 餐	MIYABI, 2F 二楼 雅日餐厅
	17:30-21:00	Buffet 晚 餐	Feast, 1F 一楼 盛宴标帜餐厅
December 19 12 月 19 日	08:30-12:10	Plenary Session 会议报告	Junior Ballroom II-I, 2F 二楼 精致宴会厅
	12:10-13:30	Buffet 午 餐	Feast, 1F 一楼 盛宴标帜餐厅
	14:00-17:00	Plenary Session 会议报告	Junior Ballroom II-I, 2F 二楼 精致宴会厅
	18:00-20:00	Banquet 晚 宴	Junior Ballroom II-I, 2F 二楼 精致宴会厅
December 20 12 月 20 日	08:30-12:05	Plenary Session 会议报告	Junior Ballroom II-I, 2F 二楼 精致宴会厅
	12:05-13:30	Buffet 午 餐	Feast, 1F 一楼 盛宴标帜餐厅

Plenary Session / 会议报告

Time/Place: December 19 Morning, Junior Ballroom II-I, 2F

时间/地点:12月19日上午　二楼精致宴会厅

Chairs: George Zheng Chen、Catherine Bessada

Time	Content
08:30-08:45	Opening address
08:45-09:10	**Separation factor of Ln/U couple in molten salt media** Valerii Smolenskii Institute of High-Temperature Electrochemistry Urals Branch of Russian Academy of Science
09:10-09:35	**Experience on fast reactor oxide fuels recycling by pyro-processes. Overview.** Alexander Bychkov Independent Nuclear expert, retired from IAEA
09:35-10:00	**Progress of Molten Salt reactor in SINAP** Cuilan Ren Shanghai Institute of Applied Physics, Chinese Academy of Sciences
Tea Break/Group Photo（10:00-10:30）	
10:30-10:50	**Uranium behaviour in molten chlorides** Pierre Chamelot University of Toulouse, France
10:50-11:10	**Electrode Reaction Characteristics of molten carbonate fuel cell and electrolysis cell** Choong-Gon Lee Hanbat National University
11:10-11:30	**Next-Generation Ionic Liquid Based Composite Patch for Accelerated Wound Healing under Extreme Temperatures** Naved Anjum Ibrahimbhai Malek Sardar Vallabhbhai National Institute of Technology
11:30-11:50	**R&D and Commercial Demonstrations of Molten Salt Energy Storage in CHN Energy** Wenjin Ding National Institute of Clean-and-Low-Carbon Energy, CHN Energy
11:50-12:10	**Molten salt electrolysis for reactive metals'upcycling** Xin Lu University of Science and Technology Beijing
12:10-13:30	Buffet

Plenary Session / 会议报告

Time/Place: December 19 Afternoon, Junior Ballroom II-I, 2F

时间/地点:12月19日下午　二楼精致宴会厅

Chairs: Xiaoli Xi、 Xianbo Jin

Time	Content
14:00-14:20	**Extraction lanthanides and uranium on reactive electrodes in “liquid metal-molten salt” system** Alena Novoselova Institute of High-Temperature Electrochemistry Urals Branch of Russian Academy of Science
14:20-14:40	**Research progress on microstructure and interfacial chemical reaction of molten salt** Yuan Qian Shanghai Institute of Applied Physics, Chinese Academy of Sciences
14:40-15:00	**Molten salt-promoted NieFe/Al_2O_3 catalyst for methane pyrolysis** Qian Xu Shanghai University
15:00-15:20	**Challenges and Solutions for Ammonia Synthesis in Molten Chloride Salt Systems: Regulating Salt Basicity to Enhance Performance** Xiaofei Guan ShanghaiTech University
Tea Break（15:20-15:40）	
15:40-16:00	**Smouldering treatment of nuclear graphite waste and potential opportunities to combine with liquid salt technologies（on-line）** Tarek Rashwan University Park, Nottingham
16:00-16:20	**Amentum UK Molten Salt Research and Development Capability（on-line）** Phil Quayle Consulting & Innovation | Energy & Environment International
16:20-16:40	**Selective Electrochemical Reduction and Anodic Dissolution of Spent Fuel Surrogates in Molten Salts** Di Hu University of Nottingham Ningbo China
16:40-17:00	**Computational Modelling of Thermal Conductivity** Xue Yong Department of Electrical Engineering and Electronics, University of Liverpool
18:00-20:00	Banquet

Plenary Session / 会议报告

Time/Place: December 20 Morning, Junior Ballroom II-I, 2F

时间/地点:12月20日上午　二楼精致宴会厅

Chairs: Bing Li、 Miao Shen

Time	Content
08:30-08:50	**In situ NMR approach of molten chlorides for fast nuclear reactors** Catherine Bessada Centre national de la recherche scientifique (CNRS), Université d'Orléans
08:50-09:10	**4D visualization of dynamic interfaces in the molten-salt electrochemistry** Weili Song Beijing Institute of Technology
09:10-09:30	**Aluminiun cathode based actinide separation over lanthanides via molten salt electrolysis** Weiqun Shi Shanghai Jiao Tong University
09:30-09:50	**Molten salt application to treatment of nuclear fuel debris** Haruaki Matsuura Tokyo City University
09:50-10:10	**Molten salt optical basicity determination and its correlation with salt properties and local structure** Yafei Wang Shanghai Jiao Tong University
Tea Break（10:10-10:30）	
10:30-10:50	**Microstructure effects on corrosion and cracking of Ni-based alloy in molten fluoride salt: from a manufacturing perspective** Litao Chang Shanghai Institute of Applied Physics, Chinese Academy of Sciences
10:50-11:10	**Technological and Industrial Progress of Recycling Secondary Tungsten Resources by Molten Salt Electrolysis** Liwen Zhang Beijing University of Technology
11:10-11:25	**Upcycling CaF_2 Sludge into Fluorochemicals in Molten $CaCl_2$** Jiahao Chen Westlake University

Plenary Session / 会议报告

Time/Place: December 20 Morning, Junior Ballroom II-I, 2F

时间/地点:12月20日上午　二楼精致宴会厅

Chairs: Bing Li、 Miao Shen

Time	Content
11:25-11:40	**Multiphysics Coupling Analysis and Structural Optimization of an Electrorefiner for Pyroprocessing of Spent Nuclear Fuel** Wenzhou Sun Shanghai University
11:40-11:55	**Physicochemical Properties and Structure of FLiBeTh Salts: Insights from Machine Learning Accelerated Molecular Dynamics Simulations** Yuan Yin School of Nuclear Science and Engineering, Shanghai Jiao Tong University
11:55-12:05	**Closing Remarks** George Zheng Chen University of Nottingham, United Kingdom
12:05-13:30	Buffet

Separation factor of Ln/U couple in molten salt media

Valeri Smolenski, Alena Novoselova
(Institute of High-Temperature Electrochemistry UB RAS, Ekaterinburg, 620066, Russia
Department of Rare Metals and Nanomaterials, Institute of Physics and Technology,
Ural Federal University, Ekaterinburg, 620002, Russia)

Abstract

Currently, the nuclear fuel cycle consists of two systems for handling spent nuclear fuel (SNF): the open nuclear fuel cycle, associated with the disposal of fission products, and the closed nuclear fuel cycle (CNFC), which involves the reprocessing of SNF. One promising option for creating a closed fuel cycle is the pyroprocessing of spent nuclear fuel in molten salts with electrochemical separation of fission products (FP) from fissile materials (FM). Electrolysis of molten salts containing FP and FM can be carried out using both inert and active electrodes.

Lanthanides are present in high-level waste as fission products. They are neutron poisons, so they must be separated from the main fuel components during spent nuclear fuel reprocessing. Due to the similar chemical and electrochemical properties of lanthanides and actinides, their effective separation requires knowledge of their electrochemical and thermodynamic properties in molten media.

Thermodynamic estimation of the separation factors of uranium (a fuel component) and lanthanum (a fission product) in molten salts shows that their separation factors on liquid gallium and aluminum electrodes can reach five orders of magnitude. It was established that the selectivity of liquid metal products was reduced in the following row: Al > Ga > Sn > Bi > In > Zn > Cd.

Aluminum has a high melting point (933.52 K) and low compatibility with the metallic construction materials that limit its application in pyrochemical technologies. Gallium is considered as a prospective liquid metal electrode material. However, Ga is a trace element, and therefore, is rather expensive for the industrial application. Cadmium is currently considered as the low-melting metal electrode for separating actinides and fission products in the pyrochemical spent nuclear fuel reprocessing. This element has the advantages of compatibility with low-carbon steels and high vapor pressure at high temperatures but it is not efficient in separating lanthanides and actinides. Alloys of gallium with other elements, e.g. aluminum or indium, can be employed instead of pure Ga. So, Ga–In and Ga–Al bimetallic electrodes are very prospective for reprocessing SNF.

This work was focused on the thermodynamic estimation of the separation factors of Ln/U couple in “liquid metal – molten salt” systems using Ga-In and Ga-Al bimetallic alloys of different compositions in order to find optimal conditions for the separation of the main components of the fuel from the fission products.

The efficiency of electrochemical separation of metals during cathodic deposition is characterized by the separation factor (θ), described by equation (1).

$$\log\theta = \frac{nF}{2.303RT}\left(E^{**}_{\mathrm{U(alloy)}} - E^{**}_{\mathrm{Ln(alloy)}}\right) \quad (1)$$

This study is focused on calculating Ln/U separation factors by creating a mathematical model based on experimental data obtained from measuring equilibrium standard potentials of uranium and lanthanide on bimetallic Ga-In and Ga-Al alloys of varying compositions. Using the universal mathematical package Maple 17 Software, the Newton interpolation polynomials characterizing the variation of the studied parameters over the entire temperature range were calculated. Three-dimensional diagrams: apparent standard potential of the alloy - composition of the bimetallic electrode - temperature are presented in Fig. 1. The nonlinear dependence of alloy potentials vs. composition of bimetallic electrodes and temperature suggests the formation of mixed Me-Ga-In alloys and/or the presence of several intermetallic compounds under equilibrium conditions.

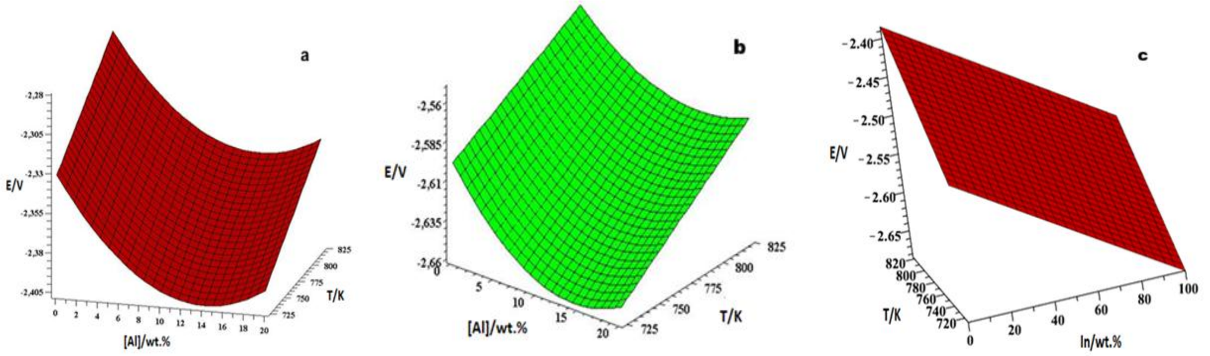

Figure 1. Variation of the apparent standard potential of Nd-Ga-Al (a), U-Ga-Al (b) and La-Ga-In (c) alloys as a function of temperature and alloy composition.

The calculation values of the excess Gibbs free energy change for α-Pr in liquid bimetallic Ga-In alloys at different temperatures are presented in Table 1. Analysis of the Table indicates that the strength of Pr in Ga-In alloys was decreased sequentially from Ga to In. Low values of the activity coefficients suggest strong interactions between lanthanide and the liquid bimetallic alloy. Increasing temperature shifts the system towards more ideal behavior.

Variation of the separation factor of Ln/U couple as a function of reverse temperature and reverse ion radius of lanthanide cations on bimetallic Ga-In and Ga-Al alloys are presented in Figs. 2, 3. It is shown that the obtained dependences are curvilinear in nature. It has been established that during the transition from lanthanides of the cerium subgroup to the yttrium subgroup (from La to Dy), there is a clear dependence of the decrease of separation factors, which may be related to the structure of the atomic shell of the f-elements.

Table 1. Variation of the excess Gibbs free energy change for α-Pr in liquid bimetallic Ga-In alloys at different temperatures.

T/K	$\Delta G^{ex}_{Dy(Ga)}$, kJ/mol	$\Delta G^{ex}_{Dy(Ga-In)}$ 20wt.% In, kJ/mol	$\Delta G^{ex}_{Dy(Ga-In)}$ 40wt.% In, kJ/mol	$\Delta G^{ex}_{Dy(Ga-In)}$ 70wt.% In, kJ/mol	$\Delta G^{ex}_{Dy(In)}$, kJ/mol
723	–199.8	–191.2	–178.5	–164.3	–145.1
751	–198.0	–189.1	–176.4	–162.3	–143.3
779	–196.2	–187.1	–174.3	–160.2	–141.5
872	–190.3	–180.4	–167.3	–153.6	–135.5
938	–186.1	–175.5	–162.3	–148.9	–131.3
1001	–182.1	–171.0	–157.6	–144.4	–127.3
1067	–177.9	–166.1	–152.6	–139.7	–123.0

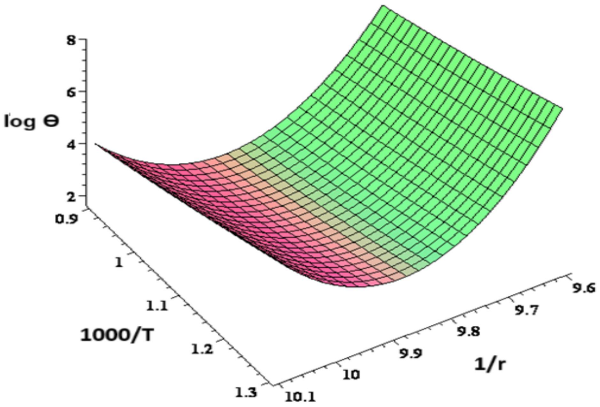

Figure 2. Three-dimensional graph for the separation factor of Ln/U couple in fused (Ga–In)/3LiCl–2KCl system.

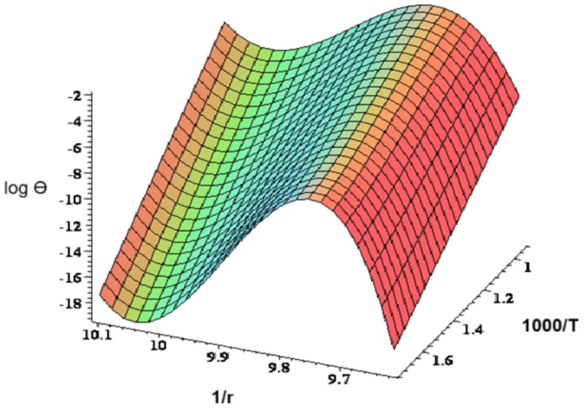

Figure 3. Three-dimensional graph for the separation factor of Ln/U couples in fused (Ga–Al)/3LiCl–2KCl system.

The separation factors for Ln/U systems were calculated. All the results are listed in Table 2. The separation factor values for Ln/U systems showed that uranium will be concentrated in the alloy phase, while lanthanides will stay in the molten salt phase. The results of the calculations indicated that high values of SF of actinides and lanthanides can be achieved for one purification stage. For the more effective separation of the actinides from the lanthanide's lower temperatures and Ga–Al alloy should be preferred. Separation factor values decreased with increasing temperature (due to the entropy factor) and increasing lanthanide's atomic number from La to Nd. Thus, the conducted studies indicate the prospects of creating a pyrochemical technology for reprocessing of spent nuclear fuel or highly radioactive waste in chloride melts using liquid metal electrodes.

Table 2. Separation factor of Ln/U couples on liquid bimetallic electrodes in molten alkaline metal chlorides at 823 K.

Element	Ekectrode	Molten salt	$E^{**}_{\text{(alloy)}}/\text{V}$	Θ
La	Ga-20 wt.% In	LiCl-KCl	–2.437	$2.63 \cdot 10^4$
	Ga-40 wt.% In	LiCl-KCl	–2.509	$6.79 \cdot 10^3$
	Ga-1.5 wt.% Al	LiCl-KCl	–2.579	$1.68 \cdot 10^5$
Pr	Ga-20 wt.% In	LiCl-KCl	–2.411	$5.89 \cdot 10^3$
	Ga-1.5 wt.% Al	LiCl-KCl	–2.537	$1.01 \cdot 10^5$
	Ga-20 wt.% In	LiCl-KCl-CsCl	–2.411	$1.95 \cdot 10^4$
	Ga-40 wt.% In	LiCl-KCl-CsCl	–2.453	$9.27 \cdot 10^3$
	Ga-70 wt.% In	LiCl-KCl-CsCl	–2.499	$6.17 \cdot 10^3$
Nd	Ga-20 wt.% In	LiCl-KCl	–2.418	$1.29 \cdot 10^4$
	Ga-40 wt.% In	LiCl-KCl	–2.453	$6.16 \cdot 10^3$
	Ga-70 wt.% In	LiCl-KCl	–2.519	$1.30 \cdot 10^3$
	Ga-1.5 wt.% Al	LiCl-KCl	–2.559	$8.51 \cdot 10^4$
	Ga-5.0 wt.% Al	LiCl-KCl	–2.574	$5.01 \cdot 10^4$
	Ga-20 wt.% Al	LiCl-KCl	–2.583	$1.14 \cdot 10^4$
	Ga-1.5 wt.% Al	LiCl-KCl	–2.417	$5.30 \cdot 10^4$

Experience on fast reactor oxide fuels recycling by pyro-processes. Overview

Alexander Bychkov
(Independent Nuclear expert, retired from IAEA.)

Progress of Molten Salt reactor in SINAP

Xiangzhou Cai
(Shanghai Institute of Applied Physics, Chinese Academy of Sciences)

Uranium behaviour in molten chlorides

Pierre Chamelot
(University of Toulouse, Frances)

Electrode Reaction Characteristics of molten carbonate fuel cell and electrolysis cell

Choong-Gon Lee
(Hanbat National University, 125 Dongseodaero, yuseong-gu, Daejeon, Korea.)

Abstract

The electrode reaction characteristics are investigated with 100 cm2 class molten carbonate cells. The fuel cell and electrolysis cell behaviors are analyzed with steady state polarization, inert gas step addition and reactant gas addition methods.

Next-Generation Ionic Liquid Based Composite Patch for Accelerated Wound Healing under Extreme Temperatures

Naved Anjum Ibrahimbhai Malek
(Sardar Vallabhbhai National Institute of Technology,Ichchanath,Surat-395007,Gujarat,India.)

Abstract

The development of multifunctional wound dressings is an emerging challenge in materials science, requiring the integration of biocompatibility, mechanical integrity, and controlled therapeutic delivery. Conventional polymer-based systems often suffer from limited drug-loading capacity and poor stability under environmental stress, limiting their clinical effectiveness.

At the Ionic Liquids Research Laboratory, SVNIT, India, our group focuses on stimuli-responsive therapeutic scaffolds capable of delivering drugs—regardless of polarity—in a controlled and sustained manner. We design a variety of soft assemblies, including micelles, vesicles, coacervates, hydrogels, and eutectogels, engineered using stimuli-sensitive Ionic Liquids (ILs) and Deep Eutectic Solvents (DESs).

Recently, we developed smart transdermal patches by integrating ILs with biocompatible metal–organic frameworks (Bio-MOFs) and polymers for wound healing under extreme temperatures. These hybrids exhibit high drug-loading efficiency, tunable release, mechanical robustness, self-healing capability, antifreezing resilience, and swelling adaptability. They enable codelivery of therapeutic agents, promoting wound repair while simultaneously mitigating infection, inflammation, and oxidative stress.

This work highlights how rational integration of ILs, Bio-MOFs, and polymers at molecular and supramolecular levels can produce next-generation soft materials with broad biomedical potential. Our approach combines green chemistry principles with advanced drug delivery technology, offering versatile platforms for localized therapy and modern healthcare applications.

R&D and Commercial Demonstrations of Molten Salt Energy Storage in CHN Energy

Wenjin Ding
(National Institute of Clean-and-Low-Carbon Energy, CHN ENERGY,No. 9 Courtyard, Binhe Avenue,
Future Science City, Changping District, Beijing.)

Abstract

Molten salt energy storage (MSES) has large-scale commercial applications in concentrating solar power (CSP) plants and industrial processes in industries (e.g., chemical industries). The global capacity of MSES in CSP is more than 70 GWh. In last five years, there are more and more demonstration projects for the application of MSES in coal-fired power plants and Carnot batteries. In CHN Energy, there are such five projects with more than 3 GWh MSES in operation or under construction, e.g., Suzhou (Anhui) project with 1 GWh MSES, Longshan (Hebei) project with 730 MWh MSES. In this presentation, the progress in R&D and commercial demonstrations of MSES in CHN Energy is presented, e.g., next-generation MSES based on molten chlorides and its corrosion control and up-scaling, commercial demonstrations of MSES.

Molten salt electrolysis for reactive metals’upcycling

Xin Lu
(University of Science and Technology Beijing, Xueyuan Road 30, Haidian, Beijing, 100083, China.)

Abstract

Reactive metals, such as aluminium, magnesium and rare-earth elements, are critical for the low-carbon society. However, extraction of these reactive metals from ore generally consumes huge energy and emits large amount of CO2. On the other hand, recycling shows great advantages to reduce the environmental impact. Different from the natural ore, many impurity elements are physically or chemically mixed during the alloying, using and discharge stages. The reactive chemical properties make remove of these impurity elements quilt difficult using the traditional remelting process, which results in a cascade recycling. On the other hand, molten slat electrolysis can efficiently separate impurity elements from reactive metals based on their potential differences. The upcycling of some typical reactive metals using the molten salt electrolysis approach will be introduced and discussed in the presentation.

Extraction lanthanides and uranium on reactive electrodes in “liquid metal-molten salt” system

Alena Novoselova, Valeri Smolenski
（Institute of High-Temperature Electrochemistry UB RAS, Ekaterinburg, 620066, Russia
Department of Rare Metals and Nanomaterials, Institute of Physics and Technology, Ural Federal University, Ekaterinburg, 620002, Russia）

Abstract

The future of nuclear power is associated with fast neutron reactors, which can significantly increase fuel burn out and expand the reproduction of fissile materials. Dry regeneration technologies, including electrochemical methods, using thermally and radiation-resistant molten salts and metals, are being developed for accelerated process of high-radiated fuel with a short cooling time of fast neutron reactors. The liquid state of metal and salt at relatively low temperatures makes it easier to solve the important problem of the phase separation for radiochemical technology. It is particularly too appropriate to use these methods for regulating the composition and continuous fuel regeneration of molten salts homogeneous reactors (MSR) – ready media for electrochemical processes. The possibilities and the ways to improve the electrochemical regeneration of spent nuclear fuel (SNF) can be revealed only on the basis of the development of the theory and experimental study of the joint electrode reactions in the molten salt – liquid metal system.

Partitioning and transmutation (P&T) concept are nowadays considered as one of the strategies to reduce the long-term radiotoxicity of the nuclear wastes. It consists in recovery of long-lived fission products from SNF and their incorporation into an inert (uranium-free) matrix with the aim of subsequent transmutation in appropriate reactors. Molten salts as a reaction media have two important advantageous properties as a solvent material in nuclear reprocessing:

- the radiation stability of molten salts allows the reprocessing of spent fuels of high radioactivity (i.e., spent fuel with a short cooling time) without any increase of solvent waste;
- since molten salts are not a neutron moderator such as water, it is possible to recycle of spent nuclear fuel with a short cooling time.

This work was devoted to study the electrochemical extraction of uranium and lanthanides on reactive Ga, Sn, Pb and Cd electrodes, the reactions of alloy’s formation, and calculation of the basic thermodynamic characteristics of alloys and separation factor of Ln/U couple in molten salt media by stationary and non-stationary research methods.

A typical cyclic voltammogram of the melt on an inert W-electrode is shown in Fig. 1(a). In the "electrochemical window" studied, one current peak was recorded, related to the reactions of deposition and dissolution of metallic uranium. No other oxidation-reduction signals are observed in this "electrochemical window". Therefore, it can be concluded that the electrochemical recovery of U(III) ions to metal on an inert W-electrode is a one-step process. To study the electrochemical processes of U(III) ion recovery on reactive electrodes leading to the formation of intermetallic compounds, uranium cathode extraction processes on Cd and Ga electrodes were investigated. Fig. 1(b, c) shows cyclic and square wave voltammograms taken on inert and reactive electrodes. It was found that a new current peak occurred at more electropositive potentials. The potential shift is related to the formation of alloys or intermetallic compounds of uranium with the reactive electrode material.

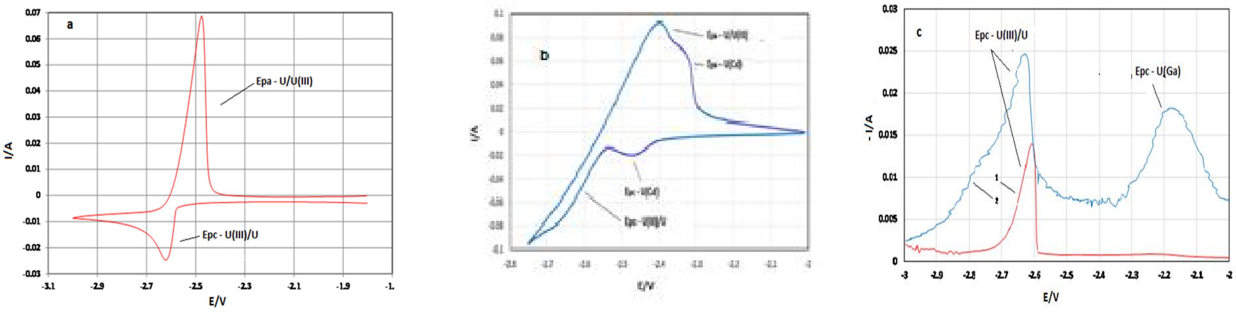

Figure 1. Cyclic (a, b) and square-wave (c) voltammograms on W (a), Cd (b) and Ga (c) electrodes in LiCl-KCl-UCl_3 melt.

To identify the composition of the cathode deposits, a potentiostatic electrolysis was carried out. The parameters of electrolysis were taken from the results of voltametric measurements. The resulting sediments were formed as a compact ingot. The X-ray phase analysis showed that it consisted of a mixture of cadmium (gallium) and intermetallic compound UCd_{11} (UGa_3), Fig. 2.

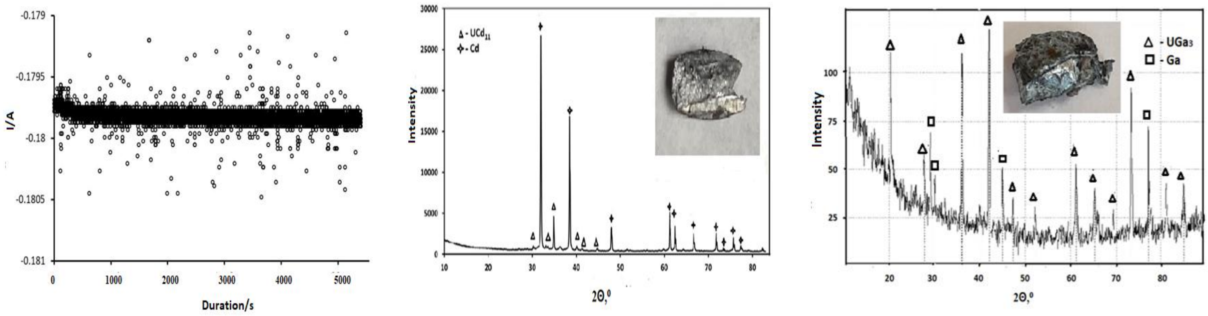

Figure 2. Parameters of potentiostatic mode of electrolysis and XRD pattern of cathode deposits on Cd and Ga electrode in LiCl–KCl–UCl3.

The effect of cathodic current density on the process of dysprosium electrodeposition on a liquid reactive electrode is shown in Fig. 3. It can be seen that at low current densities the formation of an intermetallic compounds was not detected at the cathode, Fig. 3 (lines - 1, 2). Increasing current density led to the appearance of a plateau on the potential–time dependence, which can be associated with the formation of intermetallic compound, Fig. 3 (lines - 3-5).

X-ray phase analysis of the sample obtained on a gallium electrode after electrolysis did not allow to determine its composition and structure due to its amorphous state, Fig. 4 (a). At the same time, X-ray phase analysis of the sample obtained on a cadmium electrode after molten salt electrolysis showed the formation of intermetallic compound of the composition DyCd6, Fig 4 (b).

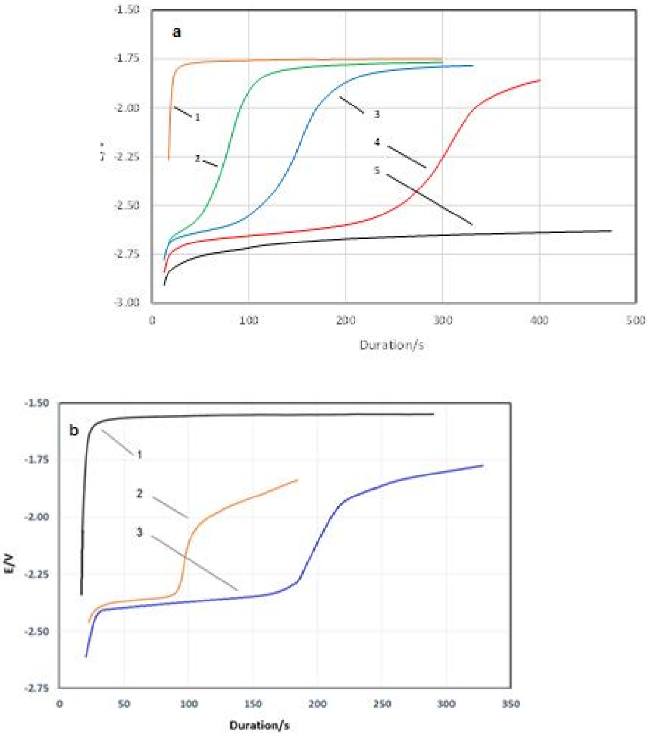

Figure 3. The potential-time dependences after short cathodic polarization of Ga (a) and Cd (b) liquid electrodes at different current values. 1 – 10 mA; 2 – 30 mA; 3 – 60 mA; 4 – 100 mA; 5 – 180 mA. Duration: 20-30 s.

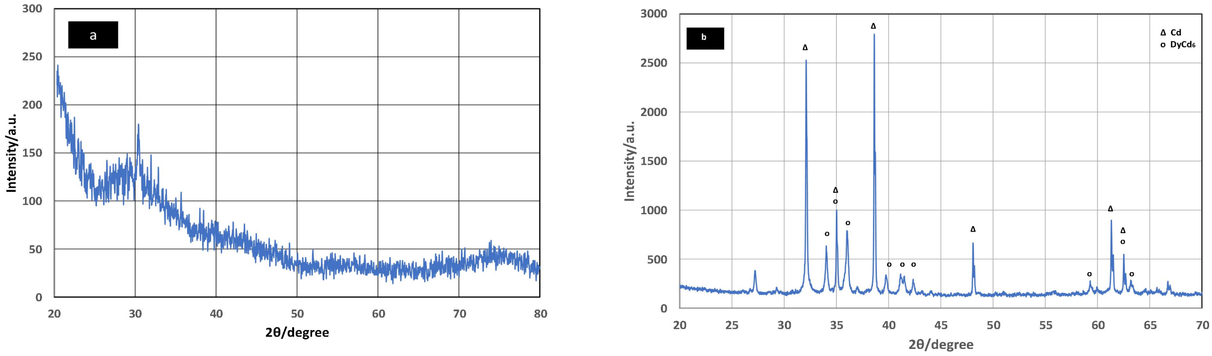

Figure 4. XRD patterns of gallium (a) and cadmium (b) cathodes after galvanostatic electrolysis of LiCl-KCl-DyCl$_3$ solutions.

The results of the carried research were used as the basis for the practical application of uranium extraction from molten salts. Thus, in order to determine the degree of uranium extraction from molten solutions, potentiostatic electrolysis was carried out on cadmium and gallium electrodes. The degree of uranium recovery on liquid reactive electrodes was more than 97%, Fig. 5. It was shown that the extraction of uranium on the reactive electrodes took place with the considerable depolarization with the formation of different intermetallic compounds. The conditions of the electrochemical production of alloys of a given composition were found.

The equilibrium standard potentials of U-Ga, U-Cd, Dy-Ga and Dy-Cd alloys were determined by open-circuit potentiometry and the temperature dependencies of the apparent standard potentials of these alloys were calculated using the Origin Pro version 7.5 software:

$$E^{**}_{\mathrm{U(Ga)}} =-(2.637 \pm 0.006) + (5.5 \pm 0.1) \cdot 10^{-4} \cdot T \pm 0.007\, V \tag{1}$$

$$E^{**}_{\mathrm{U(Cd)}} =-(2.802 \pm 0.006) + (4.1 \pm 0.2) \cdot 10^{-4} \cdot T \pm 0.004V \tag{2}$$

$$E^{**}_{\mathrm{Dy(Ga)}} =-(2.726 \pm 0.007) + (3.4 \pm 0.2) \cdot 10^{-4} \cdot T \pm 0.009\, V \tag{3}$$

$$E^{**}_{\mathrm{Dy(Cd)}} =-(2.835 \pm 0.006) + (3.5 \pm 0.1) \cdot 10^{-4} \cdot T \pm 0.007\, V \tag{4}$$

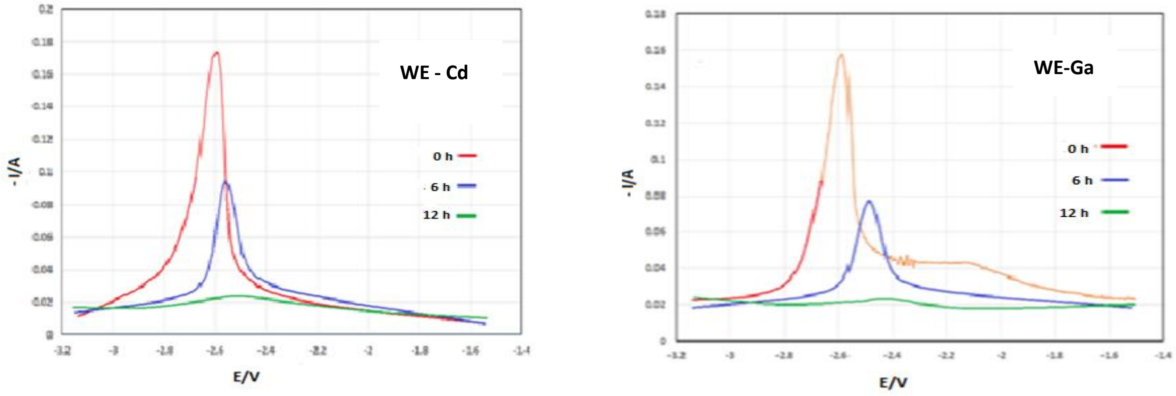

Figure 5. Electrochemical extraction of uranium from molten salts on reactive liquid electrodes.

The separation factor (SF) of Dy/U system was calculated and it was shown that uranium was concentrated in the alloy phase, while dysprosium was stayed in the molten salt phase. The results of the calculations indicated on the high influence of the nature of the reactive metal on the value of SF.

$$\log\Theta_{\mathrm{Dy/U(Ga)}} = 1.21 + \frac{2438}{T} \pm 0.04 \qquad (5)$$

$$\log\Theta_{\mathrm{Dy/U(Cd)}} = 0.91 + \frac{499}{T} \pm 0.03 \qquad (6)$$

The obtained results are summarized in Table 1.

Table 1. Separation factor of Ln/U couples on liquid metal electrodes in molten alkaline metal chlorides at 823 K.

Element	Electrode	Molten salt	$E^{**}_{\mathrm{(alloy)}}/\mathrm{V}$	Θ
Ce	In	LiCl-KCl	–2.576	$1.67{\cdot}10^3$
Pr	Ga	LiCl-KCl	–2.524	$5.89{\cdot}10^3$
Nd	In	LiCl-KCl	–2.566	$5.55{\cdot}10^2$
Dy	Ga	LiCl-KCl	–2.446	$1.48{\cdot}10^4$
	Ga	LiCl-KCl-CsCl	–2.492	$7.18{\cdot}10^4$
	Cd	LiCl-KCl-CsCl	–2.499	33.8

Table 1 presents the results of uranium-lanthanide separation on individual reactive electrodes in molten salts. It has been experimentally established that the separation factors using liquid Ga electrodes are in several orders of magnitude higher than those obtained with other liquid reactive electrodes. Therefore, gallium or its alloys may be having the significant interest for use in innovative technologies for reprocessing spent nuclear fuel

Research progress on microstructure and interfacial chemical reaction of molten salt

Yuan Qian
(Shanghai Institute of Applied Physics, Chinese Academy of Sciences)

Molten salt-promoted NieFe/Al_2O_3 catalyst for methane pyrolysis

Qian Xu
(Shanghai University)

Abstract

Bimetallic Ni-Fe/Al_2O_3 catalysts were prepared by the molten salt method, and the catalytic performance of the Ni-Fe/Al_2O_3 catalysts with KCl-$NiCl_2$ melt for methane pyrolysis was evaluated at 800°C. The catalysts and carbon products were characterized by XRD, SEM/EDS, XRF and Raman spectroscopy techniques. The results show that molten salt-promoted NieFe/Al_2O_3 catalysts exhibit high activity and long-term stability up to 1000 min on stream without any deactivation. The carbon products over the molten salt-promoted NieFe/Al_2O_3 catalysts are in the form of small granular particles instead of filamentous carbon for the catalyst without molten salt. The promotional effect of the molten salt may attribute to the higher wettability of the Fe-Ni alloy by molten salt,which can prevent the catalysts from deactivation due to carbon encapsulation.

Challenges and Solutions for Ammonia Synthesis in Molten Chloride Salt Systems: Regulating Salt Basicity to Enhance Performance

Xiaofei Guan
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Abstract

Liquid metals and molten salts have gained research attention as potential materials for ammonia synthesis. However, the alkaline species, such as nitride ions and hydride ions, dissolved in the molten LiCl－KCl salt easily absorb the ammonia and thereby limit its yield. In this presentation, I will discuss the absorption behaviors and the reaction mechanism involved. To address the issues, I will discuss various strategies, such as performing electrolysis or introducing acidic gas, for regulating the quantity of the alkaline species and mitigating their impact.

Smouldering treatment of nuclear graphite waste and potential opportunities to combine with liquid salt technologies

Tarek Rashwan
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Abstract

The UK's fleet of Advanced Gas-cooled Reactors (AGRs) utilises graphite moderator bricks, which become radiologically contaminated-primarily with Carbon-14 (C-14) and other radionuclides such as Co-60-through transmutation over decades of operation. In addition, the graphite bricks are subject to degradation through radiolytic oxidation and irradiation, causing significant cracking. As the reactors are decommissioned, managing this graphite waste presents significant technical and environmental challenges due to its condition as well as the long half-life of C-14 (~5,730 years) and other radionuclides, the volume of waste, and other persistent residual risks. Novel environmental technologies are needed to manage challenging nuclear graphite waste.

This presentation will primarily focus on exploring a novel method using applied smouldering combustion to reduce nuclear graphite bricks to ash. This process proposes to leverage a self-sustaining thermal approach where the energy contained within the graphite will destroy itself. Smouldering is emerging as an energy-efficient alternative thermal technique that has been used to successfully manage similar non-volatile carbon-based wastes commercially, e.g., spent granular activated carbon (GAC) from per- and polyfluoroalkyl (PFAS) treatment systems. Smouldering combustion is a low-temperature, flameless form of combustion – commonly seen as the glowing surface of a charcoal barbecue. The key advantage for smouldering non-volatile waste treatment compared to traditional combustion processes-e.g., flaming combustion that is used in most incinerators-is that smouldering is driven by oxygen transfer directly to the condensed phase fuel (waste). That is, the key exothermic chemical reactions in smouldering systems are driven by heterogeneous processes rather than homogeneous processes in flaming systems. In many cases, relatively simple smouldering systems can operate in a self-sustaining manner after ignition, i.e., without significant external energy inputs or operator involvement.

While smouldering systems present promise as a thermochemical treatment system to destroy nuclear graphite, they may also be paired with liquid salt methods to support nuclear graphite decontamination. That is, the energy from smouldering spent graphite may be harnessed in nearby liquid salts systems to support a dual approach: graphite volume reduction alongside graphite decontamination.

Amentum UK Molten Salt Research and Development Capability

Phil Quayle
（Amentum,B601 Faraday Street, Birchwood Park, Warrington, WA3 6GN, UK)

Abstract

Amentum UK has recently made significant investment in its ability to support Molten Salt technology vendors, supply chain and potential operators in understanding a range of salt thermophysical properties, formulation studies and general design. Alongside general chemistry, the equipment to perform corrosion studies and structural materials mechanical properties, in-situ has also been developed. This investment is in pursuit of supporting the industry in generating the necessary data to advance and justify design decisions sooner, to get this exciting technology to market in a timely manner. Phil Quayle will present the capability and take questions.

Selective Electrochemical Reduction and Anodic Dissolution of Spent Fuel Surrogates in Molten Salts

Di Hu
(University of Nottingham Ningbo China, Department of Chemical and Environmental Engineering, The University of Nottingham Ningbo China, 315100, PR China)

Abstract

To support the sustainability of advanced nuclear energy systems, a closed-loop fuel cycle with efficient spent fuel reprocessing is essential. This research, part of the UK's REFINE (A coordinated materials programme for the sustainable REduction of spent Fuel vital In a closed loop Nuclear Energy cycle) programme, explores an electrochemical route to improve material separation prior to electrorefining. We investigated a process in molten $CaCl_2$ involving the partial direct reduction of spent fuel surrogates via the FFC-Cambridge Process, followed by selective anodic dissolution. The feasibility of selective separation was tested using a CeO_2-NiO mixture, where CeO_2 serves as a surrogate for PuO_2. NiO was chosen due to its distinct electrochemical behavior.

Cyclic voltammetry (CV) successfully identified the potentials for NiO reduction and subsequent Ni metal re-oxidation. These potentials guided potentiostatic electrolysis experiments aimed at selectively removing nickel from the oxide mixture. Post-process analysis with SEM and EDX analyses confirmed the process's efficacy, revealing a threefold reduction in the atomic content of nickel within the oxide matrix. These preliminary results validate the potential of this method as a viable head-end step for pyroprocessing. Future investigations will employ surrogates like ZrO_2 (for UO_2) in compositions that more closely mimic actual spent fuel.

Computational Modelling of Thermal Conductivity

Xue Yong
(Department of Electrical Engineering and Electronics,
University of Liverpool)

Abstract

One of the key requirements for fusion-reactor materials is high thermal conductivity combined with long-term stability. However, direct measurements under extreme fusion-relevant conditions remain difficult. Computational modelling therefore provides an indispensable approach for predicting how composition, disorder, and bonding environments influence thermal transport. It also offers mechanistic insight that can guide the rational design and optimisation of materials to meet targeted performance criteria.

In this work, we demonstrate how state-of-the-art multiscale computational tools can be used to evaluate the thermal conductivity of both ordered systems (e.g., CuS_2, SnSe) and complex disordered structures. Materials such as SnSe and CuS_2 are known for their exceptionally low lattice thermal conductivity arising from strong phonon anharmonicity—properties that make them promising candidates for thermoelectric and heat-management applications.

In situ NMR approach of molten chlorides for fast nuclear reactors

Catherine Bessada
(Centre national de la recherche scientifique (CNRS), Université d'Orléans)

4D visualization of dynamic interfaces in the molten-salt electrochemistry

Weili Song
(Beijing Institute of Technology,5 Zhongguancun Southern Street, Haidian Dist.)

Abstract

Electrochemically extracting Ti in the molten salts is one of the promising technologies to achieve metal Ti, while the dynamic solid-liquid interfaces in the dark-box electrochemical processes would lead to non-uniform interfacial changes induced by the dynamic dissolution of Ti-based anodes and deposition of cathodes. In this talk, I will present recent progresses of our efforts to open the dark boxes of high-temperature electrochemical cells to understand the mechanism of dynamic/variable solid-liquid interfaces in the molten salts. To achieve the goal, in situ/operando 4D visualization methods were established to profile the dynamic interfaces in the electrochemical extraction of Ti. Based on the developed visualization apparatus and analytic method, the mechanism of non-uniform changes in the dynamic interfaces have been quantitatively revealed, and rational strategies have been established to achieve stable electrochemical extraction of Ti.

Aluminiun cathode based actinide separation over lanthanides via molten salt electrolysis

Weiqun Shi
(Shanghai Jiao Tong University)

Molten salt application to treatment of nuclear fuel debris

Haruaki Matsuura
(Tokyo City University,1-28-1, Tamazutsumi, Setagaya-ku, Tokyo 158-8557, Japan)

Abstract

By combination of fluorination and molten salt electrolysis, nuclear fuel debris simulants have been treated by various condition. Depending on the fuel debris composition of U/Zr ratio, the condition of fluorination and using molten salt baths should be selected.

Molten salt optical basicity determination and its correlation with salt prop erties and local structure

Yafei Wang
(Shanghai Jiao Tong University)

Microstructure effects on corrosion and cracking of Ni-based alloy in molten fluoride salt: from a manufacturing perspective

Litao Chang
(Shanghai Institute of Applied Physics, Chinese Academy of Sciences)

Upcycling CaF_2 Sludge into Fluorochemicals in Molten $CaCl_2$

Chen Jiahao
(Westlake University, No. 600 Dunyu Road, Xihu District, Hangzhou, Zhejiang, 310030, P.R. China)

Abstract

CaF_2 sludge is a high-fluoride solid waste mainly produced by the semiconductor industry. As high-grade fluoride resources become scarce and the demand for fluoride products continues to grow, conventional landfilling treatment no longer meets sustainability requirements. Therefore, it is necessary to develop a novel recycle technology for CaF_2 sludge.

This study proposes an upcycling strategy that uses molten salt as the reaction medium. During leaching, molten $CaCl_2$ provides leaching selectivity and a fast dissolution rate for CaF_2. During fluoride extraction, fluoride ions are selectively converted to SiF_4 gas through ion-exchange reactions. After the gaseous product is absorbed in water, it yields high-purity fluosilicic acid, a basic chemical for the fluorochemical industry.

In this work, we demonstrate a continuous process for converting CaF_2 sludge into high-purity fluorochemicals. On this basis, we preliminarily investigate the evolution of fluorine species in molten salt. This work provides a molten salt approach toward a more sustainable fluorochemical industry.

Multiphysics Coupling Analysis and Structural Optimization of an Electrorefiner for Pyroprocessing of Spent Nuclear Fuel

Wenzhou Sun, Baohua Yue, and Liuming Yan
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Abstract

High-temperature electrorefining represents a pivotal technology for pyroprocessing of spent nuclear fuel, and the electrolytic efficiency and product quality are critically governed by the temperature, flow, and current density fields within the electrorefiner. However, the harsh operational environment, characterized by high temperatures, corrosive molten salts, and intense radiation, renders the continuous and effective in-situ monitoring of these key physical fields extremely challenging, and thus impedes the process optimization and engineering scale-up of the electrorefiner.

A multi-domain physical model is established based on the actual geometry of a laboratory scale electrorefiner composing of a molten salt domain, an argon atmosphere domain, electrode domains, a crucible domain, and a stirring rod domain. And the model is solved numerically by coupling of fluid dynamics, heat transfer, mass transport of diluted species, and electrode reaction kinetics via a multi-step coupling strategy. Initially, the steady-state molten salt flow field is solved using the frozen-rotor approximation to capture the characteristics of stirring-induced forced convection. Subsequently, transient heat transfer is coupled to the fluid dynamics of the argon domain, neglecting the Joule and electrochemical heating effects originated from the electrolysis. Finally, the fully coupled model is solved to resolve the local electrochemical behavior and reaction kinetics on the electrode surfaces, and the current density distributions within various cell configurations are systematically investigated. It is predicted that the temperature homogeneity within the molten salt domain (with a maximum temperature difference of 73.8 K) presents a significant bottleneck, and this maximum temperature difference can be decreased successfully to 38.5 K by increasing the distance between the molten salt surface and the cooling cover. In addition, the Joule and electrochemical heating effects induce a local temperature increase for about 4 K near the electrodes, thus the inhomogeneous of local surface current density. Moreover, the quantitative influence on the surface current density, species distribution, and local polarization behavior are evaluated with various number of cathodes and the inter-electrode gaps. Therefore, structural optimization of electrorefiner is proposed for the overall electrolytic efficiency and deposition uniformity.

In conclusion, the multi-step, multi-domain, multiphysics coupling framework offers a unified theoretical tool and simulation support for both the structural design of the electrorefiner (e.g., anode basket configuration, cathode arrangement, and crucible geometry) and the optimization of operational parameters (e.g., temperature, electrorefining potential and current density, stirring speed, and molten salt compositions).

Keywords: Pyroprocessing of spent fuel; Design of electrorefiner; Multiphysics coupling simulation

Physicochemical Properties and Structure of FLiBeTh Salts: Insights from Machine Learning Accelerated Molecular Dynamics Simulations

Yuan Yin
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Abstract

LiF-BeF_2-ThF_4 (FLiBeTh) is a promising fuel salt for thorium-based molten salt reactors due to its excellent neutron economy and adjustable properties. However, experiments on such systems remain challenging due to high temperature, corrosiveness, and toxicity. To address these challenges, this study employs molecular dynamics simulations based on machine learning potential. Using datasets from ab initio calculation and an iterative workflow, a highly accurate machine-learning model was developed, achieving energy and force prediction errors below 1 meV/atom and 50 meV/Å, respectively. This model accurately reproduces AIMD-predicted radial distribution functions, coordination numbers, and angular distributions. Furthermore, MLMD simulations enabled the exploration of larger-scale or longtime structural characteristics, including coordination shell lifetime, ionic network formation, and physicochemical properties such as density, ionic diffusion, shear viscosity, and thermal conductivity. Results show that increasing ThF_4 concentration promotes the formation of networks composed of Be^{2+}, Th^{4+}, and F^- ions, which significantly reduces ion mobility and changing the physicochemical properties of the molten salts.

A Brief Introduction of Shanghai Institute of Applied Physics

Shanghai Institute of Applied Physics (SINAP), Chinese Academy of Sciences founded in 1959 is a national institute of comprehensive nuclear science and technology. It was formerly named the Shanghai Institute of Nuclear Research (SINR), and adopted its current name in June 2003. It has two campuses, one located in the Jiading District of Shanghai (27 hectares), a key supporting area for the Shanghai Technology Innovation Center, and the other in Wuwei (67 hektares), Gansu Province, the historic town along the famous ancient Silk Road.

The main research fields of SINAP include advanced energy science and technology, represented by Thorium Molten Salt Reactor(TMSR), efficient energy storage and conversion, as well as the application of nuclear technology in the environmental, health and materials science.

Now, SINAP has 2 research centers, 11 technical departments, and the State Key Laboratory of Thorium Energy. As of December 2024, it employed 798 staff members, including 552 scientists and engineers, among whom 133 hold professors or equivalent titles. In addition, there are 789 doctorial and master's graduate students, who are pursuing studies in a wide range of disciplines, including nuclear energy science and engineering, nuclear and particle physics, nuclear technology and application, inorganic chemistry, polymeric chemistry and physics, as well as signal and information processing.

Over the years, SINAP scientists have made over 600 remarkable achievements. More than 200 of these have been awarded by the national government, the Chinese Academy of Sciences, or Shanghai. Some notable examples include the development of 1.4 m cyclotron, on which 202Pt was synthesized, a Chinese breakthrough in new nucleotide synthesis and identification; the world's first mini cyclotron mass spectrometer; and 67Ga-labeled citrate, which is the first radiopharmaceutical in Chinese Pharmacopeias; three achievements in the field of heavy ion physics and one in bioanalytical chemistry, which won the second prize of the State Natural Science Award. Furthermore, the Shanghai Synchrotron Radiation Facility (SSRF) was awarded the First Prize of the State Scientific and Technological Progress Award, highlighting its pivotal role in advancing scientific research and technological innovation.

SINAP sponsors and edits academic journals Nuclear Techniques (in Chinese), Nuclear Science and Techniques (in English), and Radiation Research and Radiation Processing (in Chinese). Shanghai Nuclear Society, Radiation Research and Radiation Processing Society under Nuclear Society of China, with its headquarters in SINAP.

State Key Laboratory of Thorium Energy

State Key Laboratory of Thorium Energy is dedicated to addressing major national needs for advanced nuclear energy in support of the "energy independence" and "carbon peaking and carbon neutrality" goals. Its mission is to systematically tackle key scientific challenges and core technologies in liquid-fueled molten salt reactors and the thorium-uranium fuel cycle, thereby laying the groundwork for global leadership in the industrial application of thorium-based nuclear fission energy. The laboratory aspires to become an internationally recognized hub for original innovation and a leading center for cultivating top scientific talent in this field.

Research activities are organized around three primary areas: liquid-fueled reactor physics, thorium-uranium cycle radiochemistry, and specialized molten salt reactor technologies. The lab's academic leaders and core members bring extensive experience in thorium-based molten salt reactor R&D. The team includes multiple national-level scientific experts and internationally recruited scholars, forming a professional research group dedicated to advanced nuclear fission technologies.

钍基核裂变能全国重点实验室面向国家“能源独立”和“双碳”目标对先进核能的重大需求，系统解决液态燃料熔盐堆和钍铀燃料循环重大科学问题和关键核心技术，奠定在国际上率先实现钍基核裂变能工业应用的科技基础，建设国际领先的钍基核裂变能的原始创新策源地和科技创新人才培养高地。重点实验室围绕液态燃料反应堆物理、钍铀循环放射化学、特种熔盐堆技术等三个主要方向开展研究工作。重点实验室学术带头人和骨干拥有丰富的钍基熔盐堆研发经验，包括多名国家级科技人才和海外引进人才，是高水平的钍基核裂变能研究团队。

Meeting Notes

Organizers

Shanghai Institute of Applied Physics, Chinese Academy of Sciences
Molten Salts and Ionic Liquids Discussion Group, Royal Society of Chemistry