

---

# Molten Salts and Ionic Liquids 19

---

## Editors:

### **W. M. Reichert**

University of South Alabama  
Mobile, Alabama, USA

### **A. Ispas**

Technische Universitat Ilmenau  
Ilmenau, Germany

### **A. Bund**

Technische Universitat Ilmenau  
Ilmenau, Germany

### **H. C. De Long**

Air Force Office of Scientific Research  
Arlington, Virginia, USA

### **L. M. Haverhals**

Bradley University  
Peoria, Illinois, USA

### **M. Mizuhata**

Kobe University  
Kobe, Japan

### **P. C. Trulove**

United States Naval Academy  
Annapolis, Maryland, USA

### **R. A. Mantz**

Army Research Office  
Durham, North Carolina, USA

## Sponsoring Divisions:



**Physical and Analytical Electrochemistry**



**Electrodeposition**



**Energy Technology**



Published by

**The Electrochemical Society**

65 South Main Street, Building D  
Pennington, NJ 08534-2839, USA

tel 609 737 1902

fax 609 737 2743

[www.electrochem.org](http://www.electrochem.org)

**ecs**transactions™

**Vol. 64, No. 4**

---

Copyright 2014 by The Electrochemical Society.  
All rights reserved.

This book has been registered with Copyright Clearance Center.  
For further information, please contact the Copyright Clearance Center,  
Salem, Massachusetts.

Published by:

The Electrochemical Society  
65 South Main Street  
Pennington, New Jersey 08534-2839, USA

Telephone 609.737.1902  
Fax 609.737.2743  
e-mail: [ecs@electrochem.org](mailto:ecs@electrochem.org)  
Web: [www.electrochem.org](http://www.electrochem.org)

ISSN 1938-6737 (online)  
ISSN 1938-5862 (print)  
ISSN 2151-2051 (cd-rom)

ISBN 978-1-62332-184-0 (Hard Cover)  
ISBN 978-1-60768-541-8 (PDF)

Printed in the United States of America.

---

## Table of Contents

*Preface* *iii*

### **Chapter 1 Bredig Awards Dinner**

(Max Bredig Award in Molten Salt & Ionic Liquid Chemistry) Molten Salts and Ionic Liquids: Where Have We Been and Where Are We Going? An Electrochemist's Perspective 3  
*C. L. Hussey*

### **Chapter 2 New IL/MS and Mixtures**

(Invited) Ionic Liquids, Superionic Glasses, Quasi-Ionic Liquids, Quasi-Liquid Ionics, All with High Conductivities but Some with Little Fluidity. Where does the Paradigm End? 9  
*C. A. Angell*

Quest for Ether-Coordinated Superoxide Ionic Liquids 21  
*D. Ishikawa, A. Kitada, K. Fukami, K. Murase*

Lithium Based Ionogel as Solid State Electrolyte: Dynamics of Confined Ionic Liquid, a Neutron Diffusion Study 27  
*C. Cerclier, J. M. Zanotti, J. Embs, J. Le Bideau*

(Invited) Double Salt Ionic Liquids Prepared by Mixing Partially Miscible Ionic Liquids: Tuning the Solubility of Lipophilic Molecules 33  
*H. Wang, J. Pereira, A. Myerson, R. D. Rogers*

Interfacial Phenomena of Alkalimetal Carbonate on Sm-Doped Ceria for Composite Electrolytes <i>M. Mizuhata, K. Takeda, H. Maki</i>	45
Binary Ionic Liquid Mixtures for Supercapacitor Applications <i>S. Lall-Ramnarine, S. Suarez, N. Zmich, D. Ewko, S. Ramati, D. Cuffari, M. Sahin, Y. Adam, E. Rosario, D. Paterno, J. Wishart</i>	57
(3-Aminopropyl)triethoxysilane as a Model Silylamine Reversible Ionic Liquid Used as a Reversible Electrolyte <i>E. J. Biddinger, J. D. Jimenez</i>	71
Synthesis of Novel Ionic Liquids with Aromatic Trifluoroborate Anions <i>K. Iwasaki, K. Yoshii, S. Tsuzuki, T. Tsuda, S. Kuwabata</i>	83

### **Chapter 3 Structure and Properties**

(Invited) Absorption of Flue-Gas Components by Ionic Liquids <i>H. Kolding, P. Thomassen, S. Mossin, S. Kegnaes, A. Riisager, J. Rogez, G. Mikaelian, R. Fehrmann</i>	97
Electrochemical Reaction of Tris(1,10-phenanthroline)Iron Complexes in Some Amide-Type Ionic Liquids <i>Y. Katayama, M. Yoshihara, T. Miura</i>	109
Computational Study of Structure, Dynamics and Spectroscopy of Ionic Liquids <i>H. J. Kim, N. Dhumal, Y. Shim, H. Kim</i>	119
Physical-Chemical Properties of Potassium Cryolite-Based Melts Containing KBF <sub>4</sub> <i>O. Tkacheva, A. Kataev, A. Redkin, A. Rudenko, A. Dedyukhin, Y. Zaikov</i>	129
Ionic Liquid Structure in Thin Films <i>R. S. Anaredy, A. J. Lucio, S. K. Shaw</i>	135
Electrochemical Investigations of Benzil in Nonaqueous Media <i>G. T. Cheek</i>	145

Density and Molar Volume of KF-NaF-AlF <sub>3</sub> Melts with Al <sub>2</sub> O <sub>3</sub> and CaF <sub>2</sub> Additions <i>A. Dedyukhin, A. Kataev, A. Redkin, Y. Zaikov</i>	151
Electrochemical Studies of Imidazolium Carboxylate Adducts in a Room-Temperature Ionic Liquid <i>G. T. Cheek, D. F. Roeper, W. Pearson, W. E. O'Grady</i>	161
The Composition of the Second Coordination Sphere and Charge Transfer of the Nb(V)/Nb(IV) Redox Couple in Alkali Halide Melts <i>A. V. Popova, V. G. Kremenetsky, S. A. Kuznetsov</i>	171
Comparison of Some Structural Parameters of the Model Systems $nM^+[CrX_6]^{3-}$ and $3M^+[CrX_6]^{3-} + 18MCl$ (M=Na, K, Cs; X=F, Cl; n=1–6) <i>S. A. Kuznetsov, V. G. Kremenetsky</i>	183
Molybdenum(V) Species in Alkali Chloride Melts: An Electronic Absorption Spectroscopy Study <i>R. V. Kamalov, V. A. Volkovich, A. B. Ivanov, B. D. Vasin, T. R. Griffiths</i>	189
Physicochemical Properties of Nonvariant Compositions of Ternary NaF-LiF-LnF <sub>3</sub> Systems (Ln = La, Nd) <i>N. V. Faidyuk, R. N. Savchuk, A. A. Omel'chuk</i>	197
Comparison of Redox Potentials in Non-Aqueous Solvents: Silver is Not a Noble Metal in the Acidic Ionic Liquid HmimBr <i>K. Pütz, D. Himmel, V. Radtke, I. Krossing</i>	207
Solubility of Transition Metal Halides in Chloroaluminate Melts <i>V. V. Karpov, V. A. Volkovich, I. B. Polovov, O. I. Rebrin</i>	211
Corrosion of Corrosion-Resistant and High-Temperature Nickel-Based Alloys in Chloroaluminate Melts <i>A. V. Abramov, V. V. Karpov, A. Y. Zhilyakov, A. F. Gibadullina, I. B. Polovov, V. A. Volkovich, S. V. Belikov, A. V. Shak, O. I. Rebrin</i>	217
Lanthanum Activity, Activity Coefficients and Solubility in Gallium-Indium Liquid Alloys <i>A. S. Dedyukhin, A. V. Shchetinskiy, V. A. Volkovich, L. F. Yamshchikov, A. G. Osipenko</i>	227

Thermodynamic Analysis of Solutions of Oxides in the Alkali Melts <i>I. N. Skryptun</i>	235
--	-----

## Chapter 4 Electrodeposition

(Invited) Electrorefining of Na in Hydrophobic Ionic Liquids <i>M. Ueda</i>	243
Direct Electroreduction of Indium and Tin Oxides in Molten Salts <i>B. Qin, P. Cui, A. M. Martínéz, E. R. Aune, G. M. Haarberg</i>	249
Aluminum Anodization in the Low-Melting LiAlBr <sub>4</sub> -NaAlCl <sub>4</sub> -KAlCl <sub>4</sub> Molten Salt <i>C. Wang, C. L. Hussey</i>	257
Electrodeposition of Palladium in 1-Butyl-3-Methylimidazolium Chloride Ionic Liquid <i>S. Shrestha, E. Gjoka, E. J. Biddinger</i>	267
Electrochemical Behavior of Ti in Molten Fluoride-Oxide System <i>Y. Yamanaka, T. Morishige, T. Takenaka</i>	275
A New Electrodeposition Process of Crystalline Silicon Utilizing Water-Soluble KF–KCl Molten Salt <i>K. Maeda, K. Yasuda, T. Nohira, R. Hagiwara, T. Homma</i>	285
(Invited) Electrodeposition of Liquid Metals from Molten Salts <i>G. M. Haarberg</i>	293
Electrochemical Behaviour of Dissolved Iron Chloride in KCl+LiCl+NaCl Melt at 550°C <i>B. Khalaghi, E. Kvalheim, M. Tokushige, L. Teng, S. Seetharaman, G. M. Haarberg</i>	301
Electrodeposition of Mg-Ni-Al Alloy in Low Temperature Molten Salts <i>J. Xu, X. Zhang, Z. Shi, G. M. Haarberg</i>	311
Electrochemical Deposition of Alkali Metal in Low-Melting Alkali Metal Perfluorosulfonylamides <i>K. Kubota, H. Matsumoto</i>	319

Effects of Process Conditions on the Fluidised Cathode Electrochemical Reduction of Tungsten Oxide in Molten LiCl-KCl Eutectic <i>R. Abdulaziz, L. D. Brown, D. Inman, S. J. R. Simons, P. R. Shearing, D. J. L. Brett</i>	323
Molten Salt Assisted Electrochemical Separation of Spent Fuel Surrogates by Partial Direct Reduction and Selective Anodic Dissolution <i>A. Stevenson, D. Hu, G. Z. Chen</i>	333
The Behavior of Additives LiF and KF on Current Efficiency in Aluminium Electrolysis <i>P. Cui, A. Solheim, G. M. Haarberg</i>	351
An Electrochemical Study of Uranium (III) and (IV) Species in Fused Alkali Chlorides <i>D. S. Maltsev, V. A. Volkovich, E. N. Vladyskin, B. D. Vasin</i>	357
Separation of Uranium and Lanthanides in a Fused Salt – Liquid Gallium Based Alloy System <i>S. Y. Melchakov, D. S. Maltsev, V. A. Volkovich, L. F. Yamshchikov, A. G. Osipenko</i>	369
Electrochemical Properties of Molybdenum in Alkali Chloride Melts <i>A. B. Ivanov, V. A. Volkovich, P. Y. Likhachev, R. V. Kamalov</i>	377
Niobium Speciation in NaCl-KCl Based Melts: An Electrochemical and Spectroelectrochemical Study <i>I. B. Polovov, M. V. Chernyshov, D. A. Shuklin, V. A. Volkovich, O. I. Rebrin, B. D. Vasin, T. R. Griffiths</i>	389

## **Chapter 5**

### **Power and Energy**

(Invited) Applications of Ionic Liquids in Electrochemical Energy Conversion and Storage <i>J. Ma, L. Seidl, W. Ju, E. Mostafa, L. Asen, S. Martens, U. Stimming, O. Schneider</i>	407
The High Temperature Operation of Lithium Secondary Batteries with Using Ionic Liquids <i>H. Matsumoto, K. Kubota</i>	425

Inorganic-Organic Hybrid Ionic Liquid Electrolytes for Na Secondary Batteries <i>K. Matsumoto, R. Taniki, T. Nohira, R. Hagiwara</i>	433
Zn-Sn Electrochemical Cells with Molten Salt Eutectic Electrolytes and Their Potential for Energy Storage Applications <i>N. Holubowitch, S. Manek, J. Landon, C. Lippert, S. A. Odom, K. Liu</i>	439
Deposition and Dissolution of Lithium through Lithium Phosphorus Oxynitride Thin Film in Some Ionic Liquids <i>R. Furuya, Y. Katayama, T. Miura</i>	453
Indirect Methods of Determination of K:Al Mole Ratio in Molten Chloroaluminates <i>V. V. Karpov, I. B. Polovov, D. Kudryashov, D. G. Lisienko, V. A. Volkovich, A. V. Chukin, O. I. Rebrin</i>	461

## **Chapter 6** **Materials and Applications**

(Invited) Use of Fluorescence Imaging and Ionic Liquids in the Study of Carbon, Clay, and Cellulose Based-Nanomaterials <i>J. W. Gilman</i>	475
Synthesis and Characterizations of Cobalt Films Electrochemically Deposited from Aqueous and Non-Aqueous Media <i>T. Dushatinski, C. Huff, T. M. Abdel-Fattah</i>	487
Preparation of Pt Nanoparticle-Adsorbed Carbon Nanotubes Using Room Temperature Ionic Liquid and Their Use as Electrocatalyst for Oxygen Reduction <i>S. Kuwabata, K. Yoshii, T. Tsuda, T. Torimoto</i>	493
(Invited) Cellulose-Chitosan-Keratin Composite Materials: Synthesis, Immunological and Antibacterial Properties <i>M. Rosewald, F. Y. S. Hou, T. M. Mututuvvari, A. Harkins, C. D. Tran</i>	499
Laser Induced Natural Fiber Welding of Cellulosic Substrates <i>E. K. Brown, K. Dennis, L. M. Haverhals, K. D. Sweely, H. C. De Long, P. C. Trulove</i>	507



Natural Fiber Welded Composite Yarns 515  
*E. K. Brown, D. P. Durkin, E. T. Fox, L. M. Haverhals, K. D. Sweely,  
H. C. De Long, P. C. Trulove*

Electrochemical Synthesis of NiSi<sub>2</sub> from a NaCl-NaF-K<sub>2</sub>SiF<sub>6</sub> Melt on a Ni Cathode 523  
*S. A. Kochetova, A. D. Pisanenko, S. V. Devyatkin*

Carbon Fibers and Nanotubes as a Product of Interaction between Silicon Carbide and Carbonate Melt 529  
*S. V. Devyatkin*

### **Chapter 7 Special Session Honoring Charles Hussey**

The Structure of Electrodeposited Aluminum Alloys from Chloroaluminate Ionic Liquids: Let's Not Ignore the Temperature 535  
*G. R. Stafford, T. Tsuda, C. L. Hussey*

Corrosion Resistance of Aluminum Films Electroplated on Steel from Chloroaluminate Ionic Liquids Containing Toluene as a Co-Solvent 549  
*L. H. Chou, C. L. Hussey*

Electrodeposition of Al-W-Mn Alloy from Lewis Acidic AlCl<sub>3</sub>-1-Ethyl-3-Methylimidazolium Chloride Ionic Liquid 563  
*T. Tsuda, Y. Ikeda, S. Kuwabata, G. R. Stafford, C. L. Hussey*

Inkjet Printing Ionic Liquids for the Fabrication of Surface Structures on Biopolymer Substrates 575  
*K. D. Sweely, E. T. Fox, E. K. Brown, L. M. Haverhals, H. C. De Long,  
P. C. Trulove*

### **Chapter 8 Nuclear and Rare Earth Chemistry**

(Invited) An Overview of the REFINE Project --- The Sustainable Reduction of Spent Fuel Vital in a Closed Loop Nuclear Energy Cycle 585  
*D. Hu, A. Stevenson, G. Z. Chen*

Separation of Dy from Nd-Fe-B Magnet Scraps Using Molten Salt Electrolysis <i>H. Konishi, H. Ono, E. Takeuchi, T. Nohira, T. Oishi</i>	593
Selective Formation of Rare Earth-Nickel Alloys via Electrochemical Reactions in NaCl-KCl Molten Salt <i>K. Yasuda, K. Kondo, S. Kobayashi, T. Nohira, R. Hagiwara</i>	601
Electrorefining Process for the Treatment of Zr-Alloy Cladding Hull Wastes from Used Nuclear Fuels <i>C. H. Lee, Y. L. Lee, M. K. Jeon, Y. T. Choi, K. H. Kang, G. I. Park, K. T. Park</i>	609
An Electrochemical and Spectroelectrochemical Study of Ln(II) (Ln = Sm, Eu, Yb) Species in NaCl-2CsCl Melt <i>V. A. Volkovich, A. B. Ivanov, A. A. Sobolev, B. D. Vasin, T. R. Griffiths</i>	617
Charge and Mass Transfer on a La <sub>2</sub> O <sub>3</sub> Added Li/Na or Li/K Molten Carbonate Meniscus Electrode of LaNiO <sub>3</sub> Coated Au Ring for Oxygen Reduction Reaction <i>Y. Takeuchi, K. Matsuzawa, Y. Kohno, S. Mitsushima</i>	635
Author Index	645