



## CENTER FOR RESOURCE RECOVERY AND RECYCLING

<http://wpi.edu/+CR3>

**An NSF Industry/University Cooperative Research Center**



# *University Partners*

**CR<sup>3</sup>** Center for Resource  
Recovery and Recycling



**WPI**

**Worcester Polytechnic Institute**



**MINES**

**Colorado School of Mines**

**KU LEUVEN**

**KU Leuven**

# ***Our Team***

**CR<sup>3</sup>** Center for Resource  
Recovery and Recycling



**Brajendra Mishra**



**Corby G. Anderson**



**Bart Blanpain**

# ***Mission***

**CR<sup>3</sup>** Center for Resource  
Recovery and Recycling

- **The Center for Resource Recovery and Recycling (CR<sup>3</sup>) is committed to being the premier cooperative research center focused on sustainable stewardship of the earth's resources.**
- **Our focus is on helping industry address a pivotal societal need – the need to create a sustainable future. At CR<sup>3</sup> you will advance technologies that recover, recycle and reuse materials throughout the manufacturing process. These advancements will help your business reduce energy costs and increase profitability, while protecting our natural resources.**

# Our Members

CR<sup>3</sup> Center for Resource  
Recovery and Recycling

## *CURRENT MEMBERS*



## **As a CR<sup>3</sup> member your company...**

- **submits and votes on research projects undertaken annually by CR<sup>3</sup>**
- **networks with global industry leaders**
- **has royalty-free IP rights to pre-competitive research**
- **may opt to sponsor company-proprietary research that remains exclusive**
- **has access to findings from large-scale projects funded by the U.S. government or foundation grants**



## **As a CR<sup>3</sup> member your company...**

- **can recruit top students from various engineering disciplines**
- **has access to all (past and current) CR<sup>3</sup> technical reports and process data**
- **membership fee is used for research expenses only without any institutional overhead**
- **has access to characterization facilities at all member institutions**
- **can consult CR<sup>3</sup> faculty, which helps members get timely solutions to factory floor problems without additional cost**
- **can sponsor student projects (senior thesis) and industrial internships**

## **As a CR<sup>3</sup> member your company...**

**Can work with sister centers, such as:**

- **Advanced Casting Research Center (ACRC) and Center for Heat Treating Excellence (CHTE) at WPI**
  - **Kroll Institute for Extractive Metallurgy (KIEM) and Critical materials Institute (CMI) at CSM**
  - **EIT-KIC Programs at KU Leuven**
- ❖ to broaden your understanding of research in recycling at partner universities.**



## Technological and Core Competencies

- **Members and academic partners have access to the Center's pool of external expertise and scientific networks for assessing feasible scientific and technological solutions.**
- **The global perspective that comes from its international membership and academic partner affiliations is considered a Center strength.**
- **CR<sup>3</sup> functions in a way that enables all participants to help steer the development and direction of research projects.**
- **CR<sup>3</sup>'s project selection gives our academic partners the opportunity to identify gaps between proposed R&D and existing technological and core competencies.**

# Competencies...

## Core Competencies

- **Mineral Processing**
- **Thermodynamics and Kinetics**
- **Pyrometallurgy**
- **Hydrometallurgy**
- **Electrometallurgy**
- **Physical Metallurgy**
- **Inorganic Chemistry**
- **Organic Chemistry**

## Supporting Technical Competencies

- **Physical, Chemical, and Mechanical Property Testing**
- **Material Characterization**
- **Additive Manufacturing**
- **Sensor and Measurement Device**
- **Life-cycle Assessment (LCA)**
- **Commercial Feasibility Assessments**
- **Modeling and Simulation**
- **Robotics & Sorting Technology**

- **Recovery and reuse of scarce and critical materials, including urban mining;**
- **Controlling the cost of material resources used in manufacturing;**
- **Reducing waste and by-product creation from manufacturing operations and end-of-life products;**
- **Recover and reuse of polymeric wastes contaminating air, water and land;**
- **Energy efficiency;**
- **Sustainable process and product development satisfying environmental regulation and policies;**
- **Minimizing carbon and water footprints;**
- **Decreasing the depletion rate of natural resources;**
- **Ensuring materials and products with recycled content are competitive;**
- **Application of Industry 4.0 in resource management – robotics and automation, machine learning, data science.**

# ***Our Achievements***

**CR<sup>3</sup>** Center for Resource  
Recovery and Recycling

**2010-2019**

## **Projects:**

- **34 Completed Research Projects**
- **8 Current Research Project**
- **3 Projects to begin in January, 2020**

**Patents: Provisional and full patents granted: 13**

**Students Graduated & Placed: 22**

# ***Our Achievements***

**CR<sup>3</sup>** Center for Resource  
Recovery and Recycling

**2010-2019**

## **Publications:**

- **Journals: 78 (from solicitation)**
- **Conference proceedings: 40**
- **Conference presentations: 60**

**Journal Launched:** Journal of Sustainable Metallurgy (Springer)

## **Publicity & Promotion:**

- **Website, e-mail, marketing and industry press**

## **Professional Partnerships:**

- **TMS – REWAS, Engineering Solutions For Sustainability**
- **KUL – Bauxite Residue Valorization**

## **Completed Research Projects**

- **Development of Aluminum-Dross Based Materials for Engineering Application (2011)**
- **Physical and Chemical Beneficiation for Recycling of Photovoltaic Materials (2011)**
- **Recovery of Rare Earth Metals from Phosphor Dust (2011)**
- **Recycling of Bag-House Dust from Foundry Sand (2011)**
- **Molten Metal Compositional Sensing to Enhance Scrap Recycling (2012)**

## **Completed Research Projects**

- **Rare-Earth Recovery from Magnets, Catalysts, and other Secondary Resources (2012)**
- **Resource Recovery and Recycling from Shredder Residue in North America (2012)**
- **Recovery of Eu/Y from Phosphor Dust (2013)**
- **Conditioning of Machined Chips (2013)**
- **Beneficiation of Flat Panel Functional Coatings (2013)**
- **Metal Recovery via Automated Sortation (2013)**
- **Recovery of Value-Added Products from Red Mud and Foundry Bag House Dust (2013)**



## **Completed Research Projects**

- **Dezincing of Galvanized Steel (2014)**
- **Development of a Novel Recycling Process for Li-Ion Batteries (2014)**
- **Fundamental Study of Lithium Ion Battery Recovery (2014)**
- **Magnet Separation Technologies for Recycling (2015)**
- **Recovery of Zinc and Iron from EAF Dusts (2015)**
- **Synthesis of Inorganic Polymers from Metallurgical Residues (2015)**
- **Recovery of Valuable Metals from Industrial Fines (2016)**

## **Completed Research Projects**

- **Value Recovery from Mining Wastes (2016)**
- **Battery Design for Disassembly in Support of Materials Reuse (2016)**
- **Rare Earth Metals Recovery from Bauxite Residue (2016)**
- **Hydrometallurgical Treatment of e-Scrap (2017)**
- **Reuse Opportunities for Bauxite Residue (2017)**
- **Recovery of Valuable Metals from Flue Dust and Other Fines from Mechanical Treatment of e-Scrap (Dec 2018)**

## **Completed Research Projects**

- **Waste Water Treatment Sludge & High Value Grinding Swarf Recycling (Dec 2018)**
- **Separation of Eu and Y from Phosphor Dust (Dec 2018)**
- **Innovative Refining Technologies for Sb Recovery (Dec. 2018)**
- **Auto-AI Scrap Material Flow Analysis with Compositional Projections (May 2018)**
- **Pretreatment Processes of Waste Printed Circuit Boards (June 2018)**
- **Online Slag and Bullion Analysis by LIBS (June 2019)**
- **Vacuum Distillation of Complex Lead Bullion (June 2019)**

## **Current Research Projects**

- **Waterborne Paint Sludge Recycling – GM/CSM (Jan'18 – Dec '20)**
- **Copper Separation from Steel – SMS Group/WPI (July '18 – Dec '20)**
- **Optimization of Inorganic Polymers for 3D Printing – Umicore/KUL (July '18 – Dec '20)**
- **Electro-Oxidation of Metals & Inorganics in Metallurgical Operations – Umicore/KUL (Jan '18 – Dec '20)**

## **Current Research Projects**

- **Moisture Analysis of Heterogeneous Solid Material Flows – Gopher Resources/KUL (Jan '19 – Dec '21)**
- **Near-Real Time Sub-ppm Detection of Elements in Pure Metals/Alloys – East Penn/WPI (Apr '19 - Oct. '20)**
- **Optimized Sorting and Separation Techniques for Remanufacturing with Product-Centric Recycled/Reclaimed Scrap – US ARL/WPI (Apr '19 – March '21)**
- **Alternative Fluxes for Lead Bullion Refining – Metallo/CSM (June '19 – May '22)**

## **Research Funding 2010-2020**

**Industry Membership: 6.2 million USD**

**Federal funding: 1.5 million USD** (NSF to WPI/CSM)

**Leveraged Federal Funding: 4.5 million USD**

**Leveraged External Funding: 6.5 million USD**  
(industrial partners)

# ***Our Achievements***

**CR<sup>3</sup>** Center for Resource  
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## **Companies Launched**

**Kinetic Batteries, LLC**



**Kinetic Batteries**

**Battery Resources, LLC**



**BATTERY RESOURCES**

**Solvus Global, LLC**



**Solvus Global**

**Global Mineral Recovery**



**GLOBAL  
MINERAL  
RECOVERY Inc.**



# ***Our Graduates***

**CR<sup>3</sup>** Center for Resource  
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## **Employers of Graduates**

- **Air Liquide**
- **Battery Resourcers**
- **Brembo North America**
- **Boston Power**
- **Copper Environmental Consulting of Anaconda**
- **FTI Consulting**
- **Gopher Resources**
- **H.C. Starck**
- **Honeywell**
- **Idaho National Laboratory**
- **Korea Maritime and Ocean University**
- **Neles**
- **Pohang Steel Company**
- **POSCO Technical Research Labs**
- **Radikal Therapeutics**
- **Severstal Steel**
- **State Development and Investment Corporation of China**
- **Steel Dynamics Inc.**
- **Solvus Global**
- **Umicore**
- **UTRC**
- **VJ Technologies**
- **WPI**

***Join us...***

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# **Fall 2020 Center Industrial Advisory Board (IAB) Meeting**

**Online**

**October 13-14, 2020**

**For information visit:**

**<http://wpi.edu/+CR3>**