

Rahul Sarkar

Assistant Professor, Department of Materials Science and Engineering (MSE), IIT Kanpur

Kalyanpur, Kanpur, U.P:2008016, India • Tel: +91-512-2242 • Email: rsarkar@iitk.ac.in

Education

University of Utah, Salt Lake City, USA

August 2015-Sept 2019

PhD in Metallurgical Engineering

CGPA: 3.99/4

Funded by: Department of Energy (DoE) and American Iron and Steel Institute (AISI)

Supervisor: Prof. H.Y.Sohn

Dissertation: Interactions of iron, wustite and slags with selected refractory materials under flash ironmaking conditions

IIT Bombay, Mumbai, India

July 2011-June 2013

Masters in Metallurgical Engineering and Materials Science

CGPA: 9.64/10

Specialisation: Process Engineering

Supervisors: Prof. N.B.Ballal and Prof. S. Basu

Thesis: Dynamic Modelling of LD Converter Steelmaking

Jadavpur University, Kolkata, India

July 2007- May 2011

Bachelors in Metallurgical Engineering

CGPA:7.53/10

Undergraduate thesis supervisor: Prof. M.K.Mitra

Undergraduate thesis title: Isothermal and non-isothermal kinetics of Magnetite reduction by coking coal

Publications

• Journal Publications

Published articles

- Rahul Sarkar and Zushu Li “Isothermal and non-isothermal crystallization kinetics of mould fluxes used in continuous casting of steel”, Metallurgical and Materials Transactions B, available online at: <https://link.springer.com/content/pdf/10.1007/s11663-021-02099-5.pdf>
- Rahul Sarkar and H.Y.Sohn, “Interaction of magnesia-carbon refractory with ferrous oxide under the conditions of the novel flash ironmaking technology (FIT)”, Ceramics International, Vol. 46 (2020), pp. 7204-7217.

- Rahul Sarkar and H.Y.Sohn, “Interaction of magnesia-carbon refractory with metallic iron under flash ironmaking conditions”, Journal of the European Ceramic Society, Vol. 40 (2020), pp. 529-541.
- Rahul Sarkar and H.Y.Sohn, “Interaction of iron with alumina refractory under flash ironmaking conditions”, Metallurgical and Materials Transactions B, Vol.50 (2019), pp. 2063-2076.
- Rahul Sarkar and H.Y.Sohn, “Interaction of ferrous oxide with alumina refractory under flash ironmaking conditions”, Ceramics International, Vol.45 (2019), pp.15417-15428.
- Rahul Sarkar and H.Y.Sohn, “Interactions of alumina refractory with CaO-SiO₂ and CaO-SiO₂-FeO slags relevant to the novel flash ironmaking technology (FIT)”, Steel Research International, Vol. 90 (2019), pp. 1900104-1900116
- Rahul Sarkar and H.Y.Sohn, “Interactions of alumina and magnesia based refractories with iron melts and slags-A Review”, Metallurgical and Materials Transactions B, Vol.49(2018),pp.1860-1882
- Rahul Sarkar, Ushasi Roy and Dinabandhu Ghosh, “A model for dissolution of lime in steelmaking slags”, Metallurgical and Materials Transactions B, Vol.47 (2016), No.4, pp. 2651-2665
- M.K.Mishra, A.G.Rao, Rahul Sarkar, B.P.Kashyap and N.Prabhu, “ Effect of preaging deformation on aging characteristics of 2507 super duplex stainless steels”, Journal of Materials Engineering and Performance (JMEPEG), Vol.25(2016), pp.374-381
- Rahul Sarkar, Arunava Sengupta, Vimal Kumar and S.K.Chaudhury, “ Effects of alloying elements on the ferrite potential of Peritectic and Ultra-Low carbon steels”, Iron and Steel Institute Japan International (ISIJ Int.), Vol. 55(2015), No.4, pp. 781-790
- Rahul Sarkar, Pramod Gupta, Somnath Basu and N.B.Ballal, “Dynamic Modeling of LD converter steelmaking: Reaction modelling using Gibb’s free energy minimization”, Metallurgical and Materials Transactions B, Vol.46 (2015), No.2, pp. 961-976.

Submitted articles and manuscripts in preparation

- Rahul Sarkar and Zushu Li, “Isothermal crystallization kinetics of two CaO-SiO₂-CaF₂-based industrial mold fluxes for small degrees of undercooling, submitted in Metallurgical and Materials Transactions B.
- Rahul Sarkar and H.Y.Sohn, “Fe-Mg interdiffusion in magnesiowustite under flash ironmaking conditions”, manuscript in preparation, target journal: Journal of the European Ceramic Society.

• **Conference Proceedings**

Published conference proceedings

- Rahul Sarkar and H.Y.Sohn, “A model for the interaction of Fe with MgO-14.5 wt. %C refractory under flash ironmaking conditions”, Proceedings of The Minerals, Metals &

Materials Society (TMS) Annual Meeting and Exhibition to be held in San Diego in Feb 2020.

- Rahul Sarkar and H.Y.Sohn, “A kinetic model for the interaction of FeO with MgO-14.5 wt. %C refractory under the conditions of the novel flash ironmaking technology (FIT)”, accepted for publication in the Proceedings of The Minerals, Metals & Materials Society (TMS) Annual Meeting and Exhibition to be held in San Diego in Feb 2020.
- Rahul Sarkar and H.Y.Sohn, “A kinetic model for interaction of iron powder with alumina refractory relevant to the novel Flash Ironmaking Technology (FIT)”, Proceedings of Materials Science and Technology (MS&T) Conference, Portland (USA), 2019.
- Rahul Sarkar and H.Y.Sohn, “A kinetic model for interaction of iron (II) oxide with pure alumina refractory under flash ironmaking conditions”, Proceedings of Materials Science and Technology (MS&T) Conference, Portland (USA), 2019.
- Rahul Sarkar , Pramod Gupta and N.B.Ballal, “Refining of Metal Droplet in Slag using the concept of Gibbs’ Free Energy Minimization at the Slag-Metal Interface”, Proceedings of the International Conference on Science and Technology of Ironmaking and Steelmaking (STIS), Jamshedpur (India), 2013, available in CD-ROM.
- Rahul Sarkar and M.K. Mitra, “Kinetics of Reduction of Magnetite-Coking Coal Briquettes”, abstract published in proceedings of 4th National Symposium for Materials Research Scholars, MR-12, Bombay (India), 2012.

Professional Experience

- **Assistant Professor, Department of MSE, IIT Kanpur** *[Sept 2021-Present]*
- **Research Fellow, WMG, University of Warwick, UK** *[Nov 2019-May 2021]*

Project Worked in:

- **OPTILOCALHT: Optimization of local heat transfer in the continuous casting mould for casting challenging and innovative steel grades**
 - Characterization of mould powders and mould slag samples obtained from industrial trials using conventional techniques such as XRD, SEM and OM.
 - Simulation of industrial slag films in the laboratory using conventional and innovative methods.
 - Use of novel techniques such as confocal scanning laser microscopy (CSLM) and X-ray computed tomography (XCT) for characterization of crystallization, cracking, fracture strength and porosity of industrial and laboratory simulated slag films.

- **Graduate Research Assistant, University of Utah** *[August 2015-April 2019]*

Projects Worked In:

- **PhD Dissertation : Interactions of iron, wustite and slags with selected refractories under Flash Ironmaking conditions**
 - High temperature experimentation with iron/iron oxide and slags with selected refractory materials under flash ironmaking conditions.
 - Post-mortem analyses of quenched samples using X-ray diffraction and microscopic techniques like Optical Microscopy (OM) and Scanning Electron Microscopy (SEM).
 - Mapping of elements on the refractory cross-section using Energy Dispersive X-ray spectroscopy (EDX).
 - Development of suitable kinetics models for refractory-iron/iron oxide/slag interactions using solid-state diffusion and its validation using experimental work.
 - Calculation of kinetic parameters such as parabolic growth-rate constants, effective diffusivity and interdiffusion coefficient from the experimental data.
 - **Large-Scale Laboratory Testing of Flash Ironmaking Technology**
 - Active participation in the cold and hot commissioning of large-scale bench reactor facility for flash ironmaking in the University of Utah.
 - High temperature experimentation with iron/iron oxide and selected refractory materials under flash ironmaking temperatures and gas atmospheres.
 - Participation in all experimental runs on the bench reactor from May 2016-December 2017.
 - Participation in bench reactor maintenance work from May 2016-December 2017.
- **Researcher, Tata Steel Research and development** *[July 2013-Aug 2015]*

Projects Worked In:

- **Development of static model to improve ferro-alloy recovery in LD 2 plant (Leader)**
 - Data collection on the existing amounts of addition of different ferro-alloys and their chill-factors.
 - Development of a comprehensive model using **[O] at turndown** from the **sub-lance measurements**.
 - Extensive plant trials and model implementation in level 2 automation.
- **Reduction of metal losses during raking in the external Desulphurization unit in LD 2 plant (Member)**
 - Data acquisition from the plant on the metal losses during raking over the last 1 year.
 - Extensive plant trials with additions of **glass and/or lime pellet** and subsequent recommendations.

- **Establishing Heat Transfer and Solidification behavior of peritectic and low-carbon steels (Member)**
 - Development of Peritectic range predictor using **ThermoCalc** analyses and heat flux data
 - Measurement of hot ductility of solidified shell using **Gleeble**
 - Determination of shell thickness through actual temperature measurements along the mold length.
- **Masters Dissertation, IIT Bombay** [Jan 2012-June 2013]

Dissertation Title: Dynamic modeling of LD convertor steelmaking

 - *Decarburization kinetics* of high carbon *Fe-C droplets* in slag
 - Effects of the amount of **FeO** in slag, *droplet size* and *temperatures* on **decarburization rate**
 - *Mathematical model* to predict the composition and temperature of the metal and slag
 - *Mixing* characteristics of the bath by diving it into a two- reactor model
 - Effects of *metal exchange rate* and the *reactor size ratio* on mixing properties of bath
- **Undergraduate project, Jadavpur University** [May 2010-May 2011]

Project Title: Isothermal and non-isothermal kinetics of Magnetite reduction by coking coal

 - Generated *kinetic data* for magnetite reduction in the range **900°C-1100°C**.
 - Qualitative interpretation of kinetic data obtained under *isothermal* and *non-isothermal* conditions
 - Predicted the reaction mechanism to be **“Interfacial Reaction Control”** using ‘*reduced time plots*’
 - Calculated an average activation energy of the reaction using *Arrhenius plots*
- **Summer Intern project, NML Jamshedpur, India** [May’2010-July’2010]

Project Title: Examples of process analysis in metal extraction using Factsage

 - Calculated *Standard Gibbs’ Free Energy Changes*(ΔG^0 s) for reactions pertinent to **Mg extraction**
 - Constructed *binary, ternary* and *quaternary* phase diagrams for **MgO-CaO-Al₂O₃-SiO₂** system
 - Determined the theoretical *slag-metal equilibrium* composition for **Fe-Mn** production
 - Examined the *common errors* while using *Factsage* and suggested *methods* to get reliable information

Teaching Experience

- **Teaching Assistant, University of Utah** [Aug’2016-Dec’2016]
 - *High Temperature Chemical Processing (MET E 5760/6760)*

- Preparation of lecture notes and laboratory hand-outs for a class of 20, consisting of both undergraduate and graduate students
 - Grading of homework assignments and preparation of model solutions for homework problems
 - Organizing laboratory classes for the students and demonstration of laboratory procedures
 - Evaluation of mid-term and final examination answer scripts and participation in final grading
- **Teaching Assistant, IIT Bombay** *[Jan'2012-May'2013]*
 - Undergraduate course on *Thermodynamics of Materials (MM 202)* for *Spring 2012*
 - Graduate course on *Transport Phenomena (MM 659)* for *Fall 2012*
 - Graduate course on *Advanced Steelmaking (MM 624)* for *Spring 2013*

Conference Participation

- *AISTech 2019-The Iron and Steel Technology Conference and Exposition* held in Pittsburgh, PA from May 6-9, 2019. *[May'2019]*
- *Materials Science & Technology (MS&T) 2019* held in Portland, OR from September 29-October 3, 2019. *[September'2019]*
- Second international conference on “*Science and Technology of Ironmaking and Steelmaking (STIS-2013)*” held in NML, JSR from Dec. 13-16, 2013. *[December' 2013]*
- Fourth “*National Symposium for Materials Research Scholars, MR-12*” held in IIT, Bombay from May 3-5, 2012. *[May'2012]*

Relevant Skills

- High temperature experimentation using *horizontal* and *vertical tubular furnaces and confocal scanning laser microscopy (CSLM)*.
- Experience in the operation of *Large Scale Bench Reactor (LSBR)* for flash ironmaking in *University of Utah*.
- Analytical tools: *XRD, Scanning Electron Microscopy (SEM)* and *Optical Microscopy (OM)*, *thermal analysis techniques such as DSC-TGA, Electron Probe Microanalyzer (EPMA)* and *Nano-indentation*.
- Software Skills: *ThermoCalc, Factsage, Matlab, Avizo*.