Curriculum Vitae

Dr. CHENNA RAO BORRA

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Experience:

Asst. Professor Dept. of MME, IIT Kharagpur, Kharagpur, WB, India	from 10/2019
Senior Scientist ABSTCPL, Taloja, Navi Mumbai, MH, India	02/2019 – 09/2019
Postdoc Dept. of MSE, TU Delft, Delft, The Netherlands	01/2017 – 01/2019
Postdoc Dept. of Chemical Engg., KU Leuven, Leuven, Belgium.	06/2016 – 02/2016
Researcher Iron and Ferroalloys Research Group, R&D, Tata Steel, Jamshedpur, JH, India – 831001	03/2008 – 03/2013
Project Scientist/Engineer Non-Ferrous Materials Technology Development Centre, Hyderabad, TG, India – 500045	10/2004 – 02/2008

Education:

Ph.D. (Extractive Metallurgy) Dept. of Chemical Engg., KU Leuven, Leuven, Belgium	11/2013 – 06/2016
M.Tech. (Extractive Metallurgy) Dept. of Metallurgical Engg., IT-BHU, Varanasi, India	08/2002 – 07/2004
AMIIM (Metallurgical Engineering) Indian Institute of Metals, Kolkata, India	01/2000 – 12/2001
DMetE (Metallurgical Engineering) Govt. Polytechnic College, Vijayawada, India	08/1996 – 12/1999

Expertise:

- **Extractive metallurgy and recycling of metals**
- Waste utilization
- Material characterization
- Material synthesis
- Mineral chemistry

Research Supervision:

- PhD **: 6** (ongoing)
- MTech **: 15** (completed) + 2 (ongoing)

Patents: Patents granted: **3;** Filed: **8**

Publications: **27** papers published in international/national journals and book chapters
Citations: **1650;** H index: **15**.

Reviewer: Reviewed **69** manuscripts

Membership of Professional Societies:

- Member of TMS
- Life member of Indian Institute of Metals (IIM)
- Life member of Indian Institute of Minerals Engineers (IIME)

Academic scholarships and awards:

- Best presentation award at IBAAS-2018 conference
- KU Leuven's "DBOF (Special research fund)" scholarship– 2013-2016
- Best project award on global R&D day of Tata Steel – 2012

Consultancy projects:

After Joining IIT-KGP

- Lithium Ion Battery Recycling: Assessment of Current Status and Future Opportunities, **2.5L** (Completed)
- Characterization of Dross Briquettes to Control the Emissions, **8L** (Completed)
- Lanthanum Metal Production Project for Concept to Commissioning of Pilot Plants for Rare Earth and Tatanium Theme Park, **6L** (ongoing)
- Cerium Metal Production Project for Concept to Commissioning of Pilot Plants of Rare Earth and Titanium Theme Park, **6L** (ongoing)
- Recovery of Rare Earths from NdFeB Magnet Project for Concept to Commissioning of Pilot Plants of Rare Earth and Titanium Theme Park, **6L** (ongoing)
- Lab scale production of emd and emm from ferro manganese furnace dust, **23L** (ongoing)
- Lab scale process development for removal of iron from bauxite ore, **18L** (ongoing)

Research projects:

After Joining IIT-KGP

- Process development for metal recovery from indian bauxite residues (red mud) **28L** (ongoing)
- Recovery of rare earths and other major elements from NdFeB magnets, **33L** (ongoing)
- Synthesis of AlF_3 from aluminium dross, **16L** (ongoing)
- Synthesis of high purity alumina from dross, **33L** (ongoing)

ANNEX – I

RESEARCH EXPERIENCE

2019 onwards: Assistant professor (IIT-Kharagpur)

- Li-ion batteries (**LiB**s)recycling
- WEEE (**PCB**) recycling
- **NdFeB** magnet recycling
- **Red mud** utilization
- **Iron ore slimes** utilisation
- **Rare earth** metal production

2019 – 2019 (ABSTCPL)

- **Major achievement:**
  - Successfully implemented a project on "**Phosphorus reduction** from V source for the production of low phosphorus **ferro-vanadium**".
- **List of other important projects:**
  - Alkali and alumina recovery from bauxite residue
  - New process development for valuable metals recovery from a vanadium source
  - Fe removal from recycled aluminium melts
  - Production of high purity alumina

2017 – 2019 (MSE, TU Delft)

Postdoc:

- Developed several novel processes for the **recovery of cerium and lanthanum from glass polishing waste** by the pyro, hydro and electrometallurgical processes and converting the recovered rare earths to **high-value Al-(Ce, La) alloys**.
- Developed a molten (fused) salt electrolysis process for misch metal and Al-(La,Ce) alloy

2013 – 2016 (CIT, KU Leuven)

Postdoc:

- Worked on the recovery of rare earths from bauxite residue by high-pressure acid leaching (HPAL) and neutralization followed by acid leaching. Also worked on the characterization of a lead-containing landfill and calcium recovery from slag.

Ph.D.:

- **Title**: Recovery of rare earths and major metals from bauxite residue (red mud)
- **Supervisors**: Prof. Tom Van Gerven, Prof. Koen Binnemans and Prof. Yiannis Pontikes
- **Abstract**: Bauxite residue (red mud) is a waste generated in Bayer process of alumina production. Storage of this material is environmentally harmful and a space concern. Currently, there are not many large-volume applications of bauxite residue. Hence, our research was focused on the recovery of rare-earth elements (REE) and other metals from bauxite residue. In the first stage of this work, direct leaching of REEs was studied.

Dissolution of iron was high in direct leaching. Therefore, iron was removed from bauxite residue prior to leaching by smelting reduction in the presence of carbon and flux. During slag leaching, the selectivity of REEs over iron was clearly improved. However, smelting of bauxite residue requires a high amount of energy due to the presence of high amount of alumina. Therefore, the removal (and recovery) of alumina from bauxite residue by sodium carbonate roasting before smelting was studied. The sample after alumina removal was smelted without any added flux and it was possible to obtain a clear slag-metal separation. REEs were successfully recovered from slag by acid leaching from alumina-poor slags. An alternative process, called sulfation-roasting-leaching, was also developed to selectively leach the REEs.

- Supervised **two Master thesis students** during this research work.
- Organized a conference "**Redmud2015**" at Leuven, Belgium.

2008-13 (R&D, Tata Steel Ltd.)

- **Major achievements:**
  - Developed a novel hydrometallurgical process for the production of battery grade MnO_2 and Mn metal from Ferromanganese furnace dust. *An international IPR was filed*. This process was developed at lab scale. Management was asked to study it on a pilot scale.
  - Worked on a novel process for the production of cold bonded chromite pellets. Participated in the production of pellets and their characterization. This process decreases the environmental pollution by eliminating the high-temperature sintering. It was implemented in the ferrochrome plant.
  - Worked on a new process technology for production of sponge chrome. The process technology was developed from lab scale to pilot scale. This process was selected by management for commercialization. *An international (WIPO) and Indian (IPO) patents are filed to protect the IPRs*.
  - Developed a novel process for the production of alloy pig iron nuggets from composite pellets of chromite ore overburden. This process was developed from lab scale and also studied at pilot scale. This process can solve the environmental problems related to chromite ore overburden.

- **List of other important projects:**
  - Pellet chemistry optimization using thermodynamic studies. These studies were implemented in the iron ore pellet plant.
  - Developed a process for the production of iron nuggets from composite pellets of high alumina iron ore slimes (waste material).
  - Developed a process for low carbon ferroalloys production by aluminothermic reduction route.
  - Utilization of Jhama coal in the sintering process. It replaces the costly coke.
  - Thermodynamic studies of smelting - reduction reactions and computation of equilibria and slag phase diagrams using FACTSage.

2004-08 (NFTDC, Hyderabad):

- **Major achievement:**
  - Successfully led a project on "Development of a process for Molybdenum disilicide powder production." Process technology from Molybdenum ore to high purity Molybdenum disilicide ($MoSi_2$) powder production was developed on a lab scale and scaled up to pilot scale. This process includes electro oxidation (sodium hypochlorite leaching) of Molybdenite (MoS_2) concentrate, recovering molybdenum from the solution as molybdenum oxide, silico-thermal reduction of molybdenum oxide and purification of raw Molybdenum Silicide. *Pilot-scale* set up was designed, fabricated, and commissioned for the production of 10 kg batch size.
- **List of other important projects:**
  - Microwave synthesis of nanomaterials and microwave sintering of $MoSi_2$ (2007-2008) – Principal Investigator
  - Leaching of Molybdenite concentrate for preparation of high purity Molybdenite (2004-2006) – Co-investigator

ANNEX – II

Publications in journals:

SCI journals

1. S Sarkar, V Anand, R Ranjan, **CR Borra**, PP Sahoo, 2022. Elimination of Fluorspar Use and Reduction in Lime Consumption at Ladle Furnace by Reutilizing Alumina-Rich Ladle Furnace Slag. Journal of Sustainable Metallurgy, 8, 398–408. **DOI: 10.1007/s40831-022-00492-1**
2. **Borra, C. R**., Vlugt, T. J., Yang, Y., Spooren, J., Nielsen, P., Amirthalingam, M., & Offerman, S. E. (2021). Recovery of rare earths from glass polishing waste for the production of aluminium-rare earth alloys. Resources, Conservation and Recycling, 174, 105766. **DOI: 10. 1016/j. resconrec.2021. 105766**
3. Onal, M.A.R., Panda, L., Kopparthi, P., Singh, V., Venkatesan, P. and **Borra, C.R.**, 2021. Hydrometallurgical Production of Electrolytic Manganese Dioxide (EMD) from Furnace Fines. Minerals, 11(7), p.712. **DOI: 10.3390/min11070712**
4. Gollapalli V., Srinivasa Rao T., Borra C.R., Karamched P. S., Rao M. B. V., "Investigation on Stabilization of Ladle Furnace Slag with Different Additives" *Journal of Sustainable Metallurgy,* 2020 (online). **DOI: 10.1007/s40831-020-00263-w**
5. **Borra, C.R**., Vlught, T. J. H., Spooren, J., Nielsen, P., Yang, Y., Offerman, S.E., "Characterization and Feasibility Studies on Complete Recovery of Rare Earths from Glass Polishing Waste" – Metals, 2019, 9 (3) – **DOI: 10.3390/met9030278**
6. **Borra C.R.**, Vlugh, T. J. H., Yang Y., Offerma, S.E., "Recovery of Cerium from Glass Polishing Waste: A Critical Review" – *Metals,* 2018, 8 (10) – **DOI: 10.3390/met8100801**
7. Gollapalli V., Rao M. B. V., Karamched P. S., **Borra C.R.**, Roy G. G., Srirangam P. "Modification of oxide inclusions in calcium treated Al-Killed high sulphur steels" – *Ironmaking and Steelmaking*, 2018 – **DOI:10.1080/03019233.2018.1443382**.
8. Rivera R. M., Ounoughen G., **Borra C. R.**, Binnemans K., Van Gerven T., "Neutralisation of bauxite residue by carbon dioxide prior to acidic leaching for metal recovery" – *Minerals Engineering*, 2017, 112, P 92 – **DOI: 10.1016/j.mineng.2017.07.011**
9. **Borra C. R.**, Blanpain B, Pontikes Y., Binnemans K., Van Gerven T., "Recovery of rare earths and major metals from bauxite residue (red mud) by alkali roasting, smelting and leaching" – *Journal of Sustainable Metallurgy,* 2017, 3, P393 – **DOI: 10.1007/s40831-016-0103-3**
10. Bieke O., **Borra C. R.**, Binnemans K., Van Gerven T., "Recovery of scandium from sulfation-roasted leachates of bauxite residue by solvent extraction with the ionic liquid betainium bis(trifluoromethylsulfonyl)imide" – *Journal of Separation and Purification Technology,* 2017, 176, P208 – **DOI: 10.1016/j.seppur.2016.12.009**
11. Onal M.A.R., **Borra C. R.**, Guo M., Blanpain, B., Van Gerven T., "Hydrometallurgical Recycling of NdFeB Magnets: Complete Leaching, Iron Removal and Electrolysis" – *Journal of Rare Earths* – 2017, 35, P574 – **DOI: 10.1016/S1002-0721(17)60950-5**

12. Onal M.A.R., Emir A., **Borra C. R.**, Blanpain, B., Van Gerven T., Guo M., "Recycling of NdFeB Magnets using Nitration, Calcination and Water Leaching" – *Hydrometallurgy,* 2017, 167, P 115 – **DOI: 10.1016/j.hydromet.2016.11.006**

13. **Borra C. R.**, Blanpain B, Pontikes Y., Binnemans K., Van Gerven T., "Comparative analysis of processes for recovery of rare earths from bauxite residue" – *JOM,* 2016, 68, P 2958 – **DOI: 10.1007/s11837-016-2111-y**
14. **Borra C. R.**, Blanpain B, Pontikes Y., Binnemans K., Van Gerven T., "Recovery of rare earths and other valuable metals from bauxite residue (red mud): A review" – *Journal of Sustainable Metallurgy*, 2016, 2, P365 – **DOI: 10.1007/s40831-016-0068-2**
15. Yanamandra R.M., **Borra C.R**., Tripathy S.K., Ghosh T.K., Kapure G., "Alternative utilisation prospects for Indian lateritic overburden" – *Journal of Mines, Metals and Fuels*, 2016, 64, P86
16. **Borra C. R.**, Mermans J., Blanpain B, Pontikes Y., Binnemans K., Van Gerven T., "Selective recovery of rare earths from bauxite residue by sulfation-roasting-leaching" – *Minerals Engineering,* 2016, 92, P 151 – **DOI:10.1016/j.mineng.2016.03.002**
17. Roosen J., Roosendael S.V., **Borra C.R.,** Van Gerven T., Mullens S., Binnemans K., "Recovery of scandium from leachates of Greek bauxite residue by adsorption on functionalized chitosan-silica hybrid materials" – *Green Chemistry,*2016, 18, P 2005 – **DOI: 10.1039/C5GC02225H**
18. **Borra C. R**., Blanpain B, Pontikes Y., Binnemans K., Van Gerven T., "Smelting of bauxite residue (red mud) in view of selective rare earths leaching" – *Journal of Sustainable Metallurgy* –2016, 2 (1) P 28 – **DOI: 10.1007/s40831-015-0026-4**
19. Onal M.A.R., **Borra C. R.**, Guo M., Blanpain, B., Van Gerven T., "Recycling of NdFeB magnets using sulfation, selective roasting and water leaching" – *Journal of Sustainable Metallurgy,* 2015, 1, P 199 – **DOI: 10.1007/s40831-015-0021-9** Citations: **30**
20. **Borra C. R**., Pontikes Y., Binnemans K., Van Gerven T., "Leaching of rare earths from bauxite residue (red mud)"- *Minerals Engineering,* 2015, 76, P 20 – **DOI: 10.1016/j.mineng.2015.01.005**
    Citations: **128**
21. **Borra C. R.**, Dwarapudi S., Kapure G., Tathavadkar V., Denys M. B., "Effect of alumina on the slag-metal separation during iron nugget formation from high alumina Indian iron ore fines"- *Ironmaking and Steelmaking*, 2013, 40 (6), P 443 – **DOI: 10.1179/1743281212Y.0000000073**
22. Srinivas D., Vilas T., **Borra, C. R.**, Kamesh, S., Tamal, G., Debashish B., "Development of Cold Bonded Chromite Pellets for Ferrochrome Production in Submerged Arc Furnace", *ISIJ International*,2013, 53 (1), P 9 – **DOI: 10.2355/isijinternational.53.9**
23. Kapure, G., **Borra C.R**., Tathavadkar, V., Sen, R., "Direct reduction of low grade chromite overburden for recovery of metal values", *Ironmaking and Steelmaking*, 2011, 38 (8), P 590 – **DOI: 10.1179/1743281211Y.0000000028**

Non-SCI journals

24. Kapure, G., Tathavadkar, V., **Borra C.R**., Raju, K. S., Denys, M., "Effect of Preoxidation of Chromite Ore on the Ore Structure and Direct Reduction" *Steel Tech* , Vol 5, No 3, 2011, **P 19**
25. Kapure, G., **Borra C.R**., Tathavadkar, V., K. S and Denys, M., " Direct Reduction Studies on Nickeliferrous Chromite Overburden of Sukinda" *Steel Tech*, Vol 5, No 3, 2011, **P 51**
26. **Borra C.R**., Kapure, G., Tathavadkar, V., "Investigation of preoxidation of Sukinda chromite ore", *Tatasearch*, vol 1, 2010, P 145

Book Chapters

27. **Borra C. R.**, Blanpain B, Pontikes Y., Binnemans K., Van Gerven T., "Recovery of rare earths from bauxite residue (red mud)", Chapter in *"Critical Materials: Science and Technology"*, ed. Offerman S.E. and Reller A., World scientific, 2018

Publications and presentations in conference proceedings:

1. **Borra, C. R.**, Blanpain, B., Pontikes. Y., Binnemans, K., Van Gerven, T., "Recovery of rare earths and major metals from bauxite residue (red mud" *IBAAS 2018*, Mumbai, India, Spetember 2018
2. **Borra, C.R.**, Vlught, T. J. H., Yang, Y., Offerman, S.E., "Characterisation of glass polishing waste samples" *ERES2017: 2nd European Rare Earth Resources Conference' 2017,* Santorini, Greece, May 2017, P215
3. Onal M.A.R., **Borra C. R.**, Guo M., Blanpain, B., Van Gerven T., "Recycling of NdFeB Magnets with Nitration-Calcination-Water Leaching" *ERES2017: 2nd European Rare Earth Resources Conference' 2017,* Santorini, Greece, May 2017, P221
4. **Borra, C.R.**, Vlught, T. J. H., Yang, Y., Offerman, S.E., "A brief review on recovery of cerium from glass Polishing waste" *Slag Valorization Symposium' 17*, Leuven, Belgium, April 2017, P 495
5. **Borra, C. R.**, Blanpain, B., Pontikes. Y., Binnemans, K., Van Gerven, T., "Selective leaching of rare earths from bauxite residue after sulfation roasting", *Bauxite Residue Valorisation and Best Practices'15*, Leuven, Belgium**,** October 2015, P301
6. Bieke, O., **Borra, C. R.**, Van Gerven, T., Binnemans, K., "Selective recovery of scandium(III) from bauxite residue leachates by solvent extraction with a carboxyl-functionalized ionic liquid", *Bauxite Residue Valorisation and Best Practices'15*, Leuven, Belgium**,** October 2015 **,** P331
7. Roosen, J., Van Roosendael, S., **Borra, C. R.**, Van Gerven, T., Mullens, S., Binnemans, K., "Separation of scandium from leachates of greek bauxite residue by adsorption with functionalised chitosan-silica hybrid materials", *Bauxite Residue Valorisation and Best Practices'15*, Leuven, Belgium**,** October 2015, P377
8. Hertel, T., **Borra, C. R.**, Blanpain, B., Pontikes. Y., "Inorganic polymer mortars from Bauxite residue and possibility to additionally recover aluminium and sodium", *5th International Conference on Industrial and Hazardous Waste Management,* Crete, Greece, September 2016
9. **Borra, C. R.**, Blanpain, B., Pontikes. Y., Binnemans, K., Van Gerven, T., "Smelting reduction of Fe-oxides from bauxite residue in view of improved rare earths leaching", *Slag Valorization Symposium' 15*, Leuven, Belgium, April 2015, P 149
10. **Borra, C. R.,** Pontikes, Y., Binnemans, K. and Van Gerven, T. (2014). Leaching of rare earths from bauxite residue (red mud). *Sustainability through Resource Conservation and Recycling '14*. SRCR'14. Falmouth, UK, 2014 (CD-ROM)
11. **Borra, C. R.,** Kapure, G., Biswas, A., "Activation of carbothermic reduction of pyrolusite ore", *NMD-ATM 2012*, Jamshedpur, India.
12. Rama Murthy, Y., **Borra, C. R.**, Kapure, G., Tathavadkar, V., "New prospective for the utilisation of indian lateritic chromite overburden" *Proceedings of the XI International Seminar on Mineral Processing Technology (MPT-2010)*, Jamshedpur, India, 2010, P 158
13. **Borra, C. R.**, Dwarapudi, S., Kapure, G., Tathavadkar, V., "Production of Iron nuggets from high alumina iron ore fines" *NMD-ATM 2010*, Bangalore, India – Presented
14. **Borra, C. R.**, Behera, C.K., Mankhand, T. R., "Kinetics of Reduction of Nickel Oxide by Hydrogen" *NMD-ATM 2010*, Bangalore, India – Presented
15. Kapure, G., **Borra, C.R**., Tathavadkar, V., Raju, K. S., "Process For Effective Utilization Of Low Grade Chromite Overburden", *INFACON XII, Proc. of International Ferroalloy congress*, Helsinki, Finlad,2010, P377

16. Kapure, G., Tathavadkar, V., **Borra, C.R**., Rao, S. M., Raju, K. S., "Coal Based Direct Reduction of Preoxidized Chromite Ore at High Temperature", *INFACON XII, Proc. of International Ferroalloy congress*, Helsinki, Finlad,2010, P293
17. **Borra C.R**., Kapure, G., Tathavadkar, V., Leaching of Manganese from Ferro-Manganese Furnace Dust with Sulfuric Acid, *Int. Seminar on. Mineral Processing Technology (MPT 2009)*

Granted Patents:

1. 3085523: A method of manufacturing a cold formed, diffusion bonded bimetallic tube
2. 355683: An improved method for production of ferrochrome containing carbon in the range of 0.01 to 10% by weight by smelt reduction of a charge mixture.
3. 392699: A process for reduction of composite agglomerates of high alumina iron ore mineral processing rejects and natural coal in a moving hearth furnace to produce reduced metallic iron production and or iron metal agglomerates and slag.

Filed Patents:

1. 202021013621: A process for recovery of vanadium and nickel from a compound containing valuable metals. Dt. 27.03.20
2. 239/KOL/2013: Process for smelt reduction of high grade refractory chromite ores in submerged arc furnace. Dt. 28.02.13
3. 11/KOL/2012: A hydrometallurgical process for leaching manganese from furnace dust containing manganese oxides. Dt. 08.01.11
4. 361/KOL/2011: A method for direct reduction of oxidized chromite ore fines composite agglomerates in a tunnel kiln using carbonaceous reductant for production of reduced chromite product/agglomerates applicable in ferrochrome or charge chrome production. Dt. 18.03.11
5. 360/KOL/2011: a method for oxidation of non-agglomerated chromite ore fines in one of a tunnel kiln and a rotary kiln to obtain oxidized chromite ore fines for production of ferrochrome or charge chrome. Dt. 18.03.11

Journal Reviewer : 15 journals (69 manuscripts)