

## **C. V of Dr. Lakshminarayana Rao**

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### **1. Research and Education Details**

**Assistant Professor, IISc, Bangalore India**

2016 to Date

- Working in the field of cold plasma science and technology in the areas of renewable energy and wastewater treatment and recycling
- Graduated 2 Master's students. Currently supervising 6 PhD students as a main guide and 5 PhD students as Co-Guide
- 32 peer reviewed international journal articles, 25 conference proceedings, 2 book chapters, 6 granted patents and 5 patent applications submitted. One technology transfer ongoing
- Have secured funding of Rs 3.37 Crores (0.45 Million USD) as Principal investigator and Rs 22.5 Crores (3 Million USD) as Co-Principal Investigator
- Societal impact of the research: work has resulted in a large-scale water recycling project for the state which is benefitting 20 Lakh (2 Million) farmers

**Unilever Research Center, Bangalore India**

2014 to 2016

- Research scientist – Strategic Science group working in the area of cold plasma consumer applications in the field of air and water hygiene and water saving programs

**Industrial Research, PyroGenesis Canada Inc., Montreal, Canada**

2010 to 2014

**NSERC Industrial R & D Fellowship, PyroGenesis Canada Inc., Canada**

2008 to 2010

- Led a thermal plasma torch developmental program which included physical experiments and 3D steady state mathematical modeling of a thermal plasma torch. Conducted physical experiments on a 150 kW plasma torch system to improve its life. The work resulting in an improved life of the plasma torch from 150 hrs to 1000 hrs.
- Chief scientist for the development of 'Steam Plasma Arc Hydrolysis System' for destruction of Ozone Depleting Substances. Successfully designed, constructed and performed proof of concept testing on a 2 kg/hr system to achieve 99.9999% destruction and removal efficiency, with R-12 as the feed material. Led the scale up effort for a 50 kg/hr commercial system.
- Design and development of high power thermal plasma torches ranging from 30 kW to 750 kW gross power. This work so far has led to two products & three patent applications.
- Development of thermal plasma waste to energy system.
- Led all contract research efforts undertaken by PyroGenesis Canada Inc.

**Ph.D. Chemical Engineering**

2004-2007

McGill University, Montreal, Canada.

CGPA 4.0 out of 4.0

- Thesis work: Effect of Cathode Microstructure on Erosion of Copper Cathodes - An Experimental Study.
- Plan, produce and characterize nano-structured cathodes in close collaboration with the Industrial Materials Institute, a research lab of the National Research Council of Canada.
- Established qualitative and quantitative relationship between cathode microstructure and arc electrode erosion rate. Established that coatings with smaller grain sizes having 900 to 1500 micron grain size result up to 70% lower erosion rates compared to regular copper having 20 to 23 micron grains.
- Contributed towards fundamental understanding of atmospheric pressure arc movement and existence/movement of cathode spots.
- The work resulted in six journal publications.

**M.Sc(Eng). Dept. of Metallurgy**

Indian Institute of Science, Bangalore, India.

2002-2004

CGPA 6.2 out of 8.0

- Thesis work: Mathematical and Physical Modeling of Boron Carbide Manufacturing Process.
- Design, development, procurement, installation and troubleshooting of a 80 kilowatt Boron Carbide reactor (100 kg/batch) and its accessories.
- Mathematical modeling and numerical simulation of the process.
- Conducted physical experiments to validate the modeling results and established that the modeling results correlates with the experimental observations.
- Graduated with best outgoing thesis of the year.
- The work resulted in two journal publications.

**B.E. Chemical Engineering**

Bangalore University, Bangalore, India.

1996-2000

Overall average of 79.8%

- Graduated with distinction. Received University's 10th rank medal out of 500 students graduating for the year 2000.

## 2. Awards and Prizes

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| 1. Industrial Research and Development Fellowship (30,000 \$/yr ), NSERC | 2008-2010 |
| 2. W.H. Gauvin Graduate Fellowship (15,000 \$/yr ), McGill University    | 2004-2005 |
| 3. McGill Graduate Studies Fellowship (19,000 \$/yr), McGill University  | 2005-2006 |
| 4. McGill Graduate Studies Fellowship (24,000 \$/yr), McGill University  | 2006-2007 |
| 5. McGill Graduate Award (5,000 \$), McGill University                   | 2006      |
| 6. Graduate Student Research Scholarship (72,000 Rs./yr), IISc           | 2002-2004 |
| 7. Medal for the best outgoing thesis of the year 2004-2005, IISc        | 2005      |

### 3. Research Guidance

1. Graduated 2 Master's students. Currently supervising 6 PhD students as a main guide and 5 PhD students as Co-Guide
2. At PyroGenesis Canada Inc, I have lead an active research team of five people comprising of two process technicians, one post doctoral student completing his post doctoral fellowship, one chemical engineer with Masters Degree and one automation engineer with a bachelor's degree.

### 4. Research Expertise and Technical Skills

- Expertise in plasma reformers
- Expertise in design of ozonators
- Expertise in modelling of sewage treatment plants
- Expertise on design of plasma torches and plasma systems
- Expertise on design of refractory lined reactors
- Expertise on working with high power transformers and rectifiers
- Experience in installation and aligning of industrial CO<sub>2</sub> pulsed laser system.
- Proficient with characterization of plasma sprayed and HVOF sprayed coatings.
- Experience in design and development of data acquisition systems using NI Lab view.
- Adept in various material characterization tools : FESEM, EDS, AFM, XRD, Optical microscopy, high speed CCD camera imaging, Particle size distribution analysis and Two color pyrometer.
- Fluent with programming languages such as Matlab, Visual Fortran and Fluent.
- Teaching experience in Mathematical Analysis of Experimental Data and Design Principles in Environmental Engineering Courses.

#### 4.1 Personal Details

Date of Birth	:	28 <sup>th</sup> of November 1978
Marital Status	:	Married
Nationality	:	Indian

Dr. Lakshminarayana Rao - List of Publications  
Journal Publications- Accepted/Published

1. Ananthanarasimhan N J and **Lakshminarayana Rao**, Influence of transitional and turbulent flow on electrical, optical, morphological and chemical characteristics of a nitrogen rotating gliding arc, *Journal of Physics D: Applied Physics*, 55, 2022, 245202-245219. <https://doi.org/10.1088/1361-6463/ac5bcc>
2. Anam Adil, Anand M Shivapuji and **Lakshminarayana Rao**, Thermodynamic analysis for methanol synthesis using biomass-derived syngas, *Biomass Conversion and Biorefinery* <https://doi.org/10.1007/s13399-022-02338-y>
3. Ananthanarasimhan N J Adarsh R and **Lakshminarayana Rao**, Arc diameter estimation of a rotating gliding arc using a simple high-speed camera and “Gaussian fit” function, *IEEE Transactions on Plasma Science*. <https://doi.org/10.1109/TPS.2022.3145497>
4. Anam Adil, and **Lakshminarayana Rao**, Methanol production from biomass: analysis and optimization, *Materials Today: Proceedings*, <https://doi.org/10.1016/j.matpr.2021.12.450>
5. Reshma Mohan, Mohan Kumar M S, Chanakya H N and **Lakshminarayana Rao**, Optimization of Biological Nutrient Removal in a Sewage Treatment Plant through Process Modelling and Simulation, *Journal of Water Process Engineering*, 45, 2022, 102461, <https://doi.org/10.1016/j.jwpe.2021.102461>
6. Anand M S, Dasappa S and **Lakshminarayana Rao**, Assessment of planar laminar flame speed of Hythane generated in-situ from non-thermal plasma reforming of Methane: Flame tube-based experiments and thermo-chemical analysis, *Thermal Science and Engineering Progress*, 29 (2022) 10117 <https://doi.org/10.1016/j.tsep.2021.101179>
7. Priyanka Jamwal, Anjali V Raj, Anusree K Anju, Praveen Kumar, Durba Biswas, **Lakshminarayana Rao**, Rachel Helliwell, Samia Richards, Rowan Ellis, Nazli Koseoglu, Jagadeesh Yeluripati and Stephanie Connelly, A novel approach to baseline water quality assessment at local and catchment scale: A case study from southern region, India, *Environ Monit Assess* 193, 837 (2021). <https://doi.org/10.1007/s10661-021-09617-7>
8. Priyanka Tripathi, and **Lakshminarayana Rao**, Single particle and Packed bed studies of High Ash and High Plastic Content Refused Derived Fuel, *Fuel*, 308, 2022, 121983-121995. <https://doi.org/10.1016/j.fuel.2021.121983>
9. Harsha Rao, **Lakshminarayana Rao** and H N Chanakya, Fate of Heavy Metals in Sewage Systems, *Current Science*, 121, 2021, [154.pdf \(currentscience.ac.in\)](https://www.currentscience.ac.in/pdf/cs/121/154.pdf)

10. Samia Richards, **Lakshminarayana Rao**, Stephanie Connelly, Anjali Raj, Lakshmi Raveendran, Shahana Shirin, Priyanka Jamwal and Rachel Helliwell, Sustainable water resources through harvesting rainwater and the effectiveness of a low-cost water treatment, *Journal of Environmental Management*, 286, 2021, 112223-112231  
<https://doi.org/10.1016/j.jenvman.2021.112223>.
11. Ananthanarasimhan N J, Reetesh G, Leelesh. P, Srikar P S, Anand M Shivapuji and **Lakshminarayana Rao**, Estimation of electron temperature and density of argon rotating gliding arc discharge using spectroscopic, and physical–electrical measurements, *Journal of Applied Physics*, 129, 223301-223317, 2021  
<https://doi.org/10.1063/5.0044014>
12. Ananthanarasimhan N J, Anand M Shivapuji and **Lakshminarayana Rao**, Simulation of Velocity Evolution of a Cold Collision-less Non-Magnetised Plasma by Particle-in-Cell Method, *Front Adv Mat Res*, 2, 2, 2020,18-25.  
<https://doi.org/10.34256/famr2023>
13. P S Ganesh Subramanian, Leelesh P, Anand M Shivapuji, Pierre-Luc G, and **Lakshminarayana Rao**, Plasma Activated Water from DBD as a source of Nitrogen for Agriculture: Specific Energy and Stability Studies, *Journal of Applied Physics*, 129, 2021, 093303-093314  
<https://doi.org/10.1063/5.0039253>
14. Priyanka Jamwal, Anjali V Raj, Stephanie Connelly, Jagadeesh Yeluripati, Samia Richards, **Lakshminarayana Rao** and Matteo Tamburini, Evaluating the performance of planted and unplanted HSSF-constructed wetlands: A case study from southern India, *Ecological Engineering*, 162, 2021,106170-106181  
<https://doi.org/10.1016/j.ecoleng.2021.106170>
15. Reshma Mohan, Mohan Kumar and **Lakshminarayana Rao**, CFD Multiphase Simulation of Oxygen Transfer from Diffused Aeration System in Synthetic Wastewater, *Journal of Water Process Engineering*, 40, 2021,101920 <https://doi.org/10.1016/j.jwpe.2021.101920>
16. P. S. Ganesh Subramanian, Anjali V Raj, Priyanka Jamwal, Stephanie Connelly, Jagadeesh Yeluripati, Samia Richards, Rowan Ellis and **Lakshminarayana Rao**, Decentralized Treatment and Recycling of Greywater from a School in Rural India, *Journal of Water Process Engineering*, 38, 2020, 101695  
<https://doi.org/10.1016/j.jwpe.2020.101695>
17. Amit Kumar, Ananthanarasimhan J, Anand M S, Dasappa S and **Lakshminarayana Rao**, Experimental Investigations of Non catalytic Cold Plasma Water Gas Shift Reaction, *Journal of Physics D: Applied Physics*,53, 2020, 465205  
<https://doi.org/10.1088/1361-6463/aba92d>
18. P S Ganesh Subramanian, Aditi Jain, Anand M Shivapuji, Nagalingam R Sundaresan, S Dasappa, and **Lakshminarayana Rao**, Plasma activated water from a dielectric barrier

discharge plasma source for the selective treatment of cancer cells, *Plasma Processes and Polymers*, 17, 8, 1900260-1900273, 2020.  
<https://doi.org/10.1002/ppap.201900260>

19. Ananthanarasimhan J, **Lakshminarayana Rao**, Anand M Shivapuji and Dasappa S, Influence of gas dynamics on arc dynamics and discharge power of rotating gliding arc, *Plasma Sources Sci. Technol*, 28, 2019, 085012.  
<https://doi.org/10.1088/1361-6595/ab2169>
20. Seema Sukhani, Punith N, Atharva Ekatpure, Gautami Salunke, Manjari M, Harsha Rao, H N Chanakya and **Lakshminarayana Rao**. Understanding potential of using plasma activated water as nitrogen source for algal growth: A Microcosm study, *IEEE Transactions on Plasma Science*, 49, 2, 551-556, 2021
21. Ananthanarasimhan J, Anand M Shivapuji, Leelesh P and **Lakshminarayana Rao**, Effect of Gas Dynamics on Discharge Modes and Plasma Chemistry in Rotating Gliding Arc Reactor, *IEEE Transactions on Plasma Science*, 49, 2, 502-506, 2021.  
<https://doi.org/10.1109/TPS.2020.2994580>
22. Ganesh Subramanian P S, Harsha R, Manju D. K., Hemanth M, **Lakshminarayana R**, Anand M S and Dasappa S, Characterization of Plasma Activated Water for Medical Applications, *Advanced Materials Letter*, 10, 12, 919-923, 2019  
<https://doi.org/10.5185/amlett.2019.0041> ;
23. Punith N, Harsha R, **Lakshminarayana R**, Hemanth M, Anand M S and Dasappa S, Plasma activated water generation and its application in agriculture, *Advanced Materials Letter*, 10, 10, 700-704. 2019  
<https://doi.org/10.5185/amlett.2019.0042> ;
24. Seema Sukhani, Punith N, **Lakshminarayana R** and Chanakya H N., Plasma activated water as a source of nitrogen for algae growth, *Advanced Materials Letter*, 10, 11, 797-801, 2019  
<https://doi.org/10.5185/amlett.2019.0043> ;
25. Ananthanarasimhan N J, **Lakshminarayana R**, Anand M Shivapuji and Dasappa S, Characterization and Applications of Non-Magnetic Rotating Gliding Arc Reactors - A Brief Review, *Front Adv Mat Res*, 1, 1, 31-38, 2018,  
<https://doi.org/10.34256/famr1916> ;
26. Ananthanarasimhan J, Leelesh P, Anand M Shivapuji, and **Lakshminarayana Rao**, Validation of Projected Length of the Rotating Gliding Arc Measured using Regionprops function, *Plasma Research Express*, 2, 035008, 2020.  
<https://doi.org/10.1088/2516-1067/abae49> ;
27. J. Tavares, **L. Rao**, C. Derboghossian, P. Carabin, A. Kaldas, P. Chevalier, and G. Holcroft, Large-Scale Plasma Waste Gasification, *IEEE Transactions on Plasma Science*: 39 (11), 2908-2909, 2011.

28. **M.P.L.N. Rao**, Gupta, G.S., Manjunatha, P., Kumara, S., Surib, A.K., Krishnamurthy, N., Subramanian, C. Core temperature measurement in carbothermal reduction processes. *Thermochimica Acta*, 482: 66 (7 pages), 2009.
29. **M.P.L.N. Rao**, Gupta, G.S., Manjunatha, P., Kumara, S., Surib, A.K., Krishnamurthy, N., Subramanian, C. Temperature measurements in the boron carbide manufacturing process- A hot model study. *Int. Journal of Refractory Metals & Hard Materials*, 27 (3), 621–628, 2009.
30. D'Sa K., **Lakshminarayana Rao**, and Munz, R. J. Effect of cathode microstructure on arc velocity and erosion rate of cold-sprayed copper cathodes in a magnetically rotated atmospheric pressure arc. *Journal of Thermal Spray Technology*, 17 (4): 574-582, 2008.
31. **Lakshminarayana Rao**, and Munz, R. J. E Effect of cathode microstructure on arc velocity and erosion rate of cold cathodes in magnetically rotated atmospheric pressure arcs. *Journal of Physics D: Applied Physics*, 41: 165201 (11 pages), 2008.
32. **Lakshminarayana Rao**, Munz, R. J. and Meunier, J-L. Vacuum arc velocity and erosion rate measurements on nanostructured plasma and HVOF spray coatings. *Journal of Physics D: Applied Physics*, 40 (14): 4192-4201, 2007.
33. **Lakshminarayana Rao**, and Munz R. J. Effect of surface roughness on erosion rates of pure copper coupons in pulsed vacuum arc system. *Journal of Physics D: Applied Physics*, 40 (24): 7753-7760, 2007.
34. **Lakshminarayana Rao**, Munz, R. J. and Coulombe, S. Observation of atmospheric pressure arc on a cold cathode. *Applied Physics Letters*, 91: 141502-4, 2007.
35. **Lakshminarayana Rao**, Reddy N.K., Coulombe, S., Meunier, J-L., and Munz, R. J. Carbon nanotubes as nanoparticles collector. *Journal of Nanoparticle Research*, 9 (4): 689-695, 2007.

## Abstracts/papers submitted to International Conferences

1. Anam A and **Rao, L.**, Methanol Synthesis from Biomass Gasification., International Conference on Engineering for Waste and Biomass Valorisation, Copenhagen, Denmark, June 27-30, 2022, Submitted
2. Priyanka T and **Rao, L.**, Effect of Plastic Content And Pelletisation Method On Physical, Chemical, And Thermal Properties Of Refuse Derived Fuel., International Conference on Engineering for Waste and Biomass Valorisation, Copenhagen, Denmark, June 27-30, 2022, Submitted

3. Chakraborty, A., Muddu, S., **Rao, L.**, Assessment of the Carbonate Weathering Carbon Sink Potential of Indian Ecosystems for the 21st Century, Goldschmidt2021 Virtual - 5584, 4-9 July, 2021.Submitted
4. Chakraborty, A., Muddu, S., and **Rao, L.**, Assessment of Impact of Hydroclimatic Disturbances on Terrestrial GPP Extremes of India Under Land Use and Climate Change, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-4195, <https://doi.org/10.5194/egusphere-egu21-4195>, 2021
5. Chakraborty, A., Muddu, S., **Rao, L.**, Assessment of Spatial Variations and the Interaction of Climate-Soil-Human Drivers of India's Terrestrial Carbon Use Efficiency. [Paper number: B108-0012], 2020 Fall Meeting, AGU, San Francisco, CA, 1-17 December.
6. Chakraborty, A., Muddu, S., **Rao, L.**, Assessment of Carbon Storage of India's Terrestrial Ecosystems and Important Drivers: A Remote Sensing Approach. In National Symposium on Remote Sensing for Environment Modelling & Climate Change Assessment: Opportunities and Challenges, Space Applications Centre (ISRO), Ahmedabad, Page 132 – 133, 18-19 December, 2020. Retrieved from [https://isrsns2020.in/img/ISRSNS\\_2020\\_Abstract\\_Volume.pdf](https://isrsns2020.in/img/ISRSNS_2020_Abstract_Volume.pdf)
7. Kapudeep K, Punith N, P S Ganesh Subramanian, Manju D K, Dipshikha Chakravortty, and **Lakshminarayana Rao**, Antimicrobial Study Of The Plasma Activated Water Using E. coli, 8th International Conference on Plasma Medicine, August 01~06, 2021 / Songdo Convensia, Incheon, Korea. *Accepted.*
8. Reshma Mohan T, Seetha Lakshmi, **Lakshminarayana Rao** and M.S. Mohan Kumar, Numerical Simulation of Hydrodynamics and Bio-Chemical Membrane Fouling in Porous Media, AGU Fall Meeting, San Francisco, 7 – 11 December 2020,
9. Reshma Mohan T, **Lakshminarayana Rao** and M.S. Mohan Kumar, Oxygen Transfer Predictions for Diffused Aeration System in Wastewater Treatment Plants: A Numerical Approach, AGU Fall Meeting, San Francisco, 9 – 13 December 2019.
10. Ananthanarasimhan N J, **Lakshminarayana R**, Anand M Shivapuji and Dasappa S, Observation of Arc Rotation and Voltage characteristics in Rotating Gliding Arc, Proceeding of the 24th International Symposium on Plasma Chemistry, Naples, Italy, June 9<sup>th</sup> –14<sup>th</sup>, 2019
11. Harsha Rao, Punith Narayanappa, **Lakshminarayana Rao**, Anand M Shivapuji, and Dasappa, S, Plasma activated water generation, characterization and application for seed germination and plant growth, Proceeding of the 24th International Symposium on Plasma Chemistry, Naples, Italy, June 9<sup>th</sup> –14<sup>th</sup>, 2019



12. Sharath Chandra, Niveditha, Chanakya H N, Puttanna C and **Lakshminarayana Rao**, Wastewater treatment and recycling in a bus depot-a case study from Bangalore, Proceedings of ICONSWM 2019, Bhubaneswar, India
13. Priyanka Tripathi, **Lakshminarayana Rao**, Anand Shivapuji and S. Dasappa, Status of Municipal Solid Waste generation in the world and in India with emphasis on refused derived fuel production and its utilization, Proceedings of ICONSWM 2019, Bhubaneswar, India
14. Reshmi Das, Chanakya H N and **Lakshminarayana Rao**, Water Quality assessment of Bellandur lake, Bangalore Karnataka, Proceedings of ICONSWM 2019, Bhubaneswar, India
15. P. Narayanappa, A. Singh, **L. Rao** and S. Dasappa, Decentralized Grey Water Recovery System Using Cold Plasma for Rural India, Proceeding of the 23rd International Symposium on Plasma Chemistry, Montreal, Canada, July 30<sup>th</sup> –August 4<sup>th</sup>, 2017
16. Amit Kumar., Anand M.S., **Rao L.** and Dasappa S., Cold Plasma Methane Reforming, Proceedings of the 11th Asia-Pacific Conference on Combustion, The University of Sydney, NSW Australia, 10th -14th December 2017. Volume 1, Page # 686-689; ISBN # 9781510856462
17. A. Carkner, **L. Rao**, A. Kaldas, P. Carabin, A. Ross, “Destruction of Ozone Depleting Substances using Steam Plasma”, 31st International Conference on Incineration and Thermal Treatment Technologies, New Orleans, LA, October 22-24, 2012.
18. **L. Rao** and P. Carabin, Thermal Plasma Torches for Metallurgical Applications, COM 2012 Conference of Metallurgists held in conjunction with Pressure Hydrometallurgy, Niagara Falls, Canada, Sept 30 to Oct 3 2012, accepted for Publication. 2012.
19. P. Carabin, **L. Rao** and A. Ross, « Destruction de SACO par plasma de vapeur », Salon des Technologies Environnementales du Québec – STEQ 2012, Québec (Québec), Canada, 14 March 2012.
20. **L. Rao**, P. Carabin, and G. Holcroft, Plasma Waste Gasification: Decentralized Approach to Production of Energy From Waste, 2nd International Conference on Hazardous and Industrial Waste Management, Chania, Crete, Greece, 5-8 October, 2010.
21. **L. Rao**, Plasma Technology Mini-course, 8th World Congress of Chemical Engineering, Montreal, QC, Canada, August 23-27, 2009.
22. N.Y. Mendoza Gonzalez, **L. Rao**, P. Carabin, A. Kaldas, J.L. Meunier, A Three-Dimensional Model of a DC Thermal Plasma Torch for Waste Treatment Applications, Proceeding of the 19th International Symposium on Plasma Chemistry, Bochum, Germany, July 27-31, 2009.

23. **L. Rao**, C. Guédéhoussou, C. Derboghossian, A. Kaldas, A., and P. Carabin, Validation of the Plasma Resource Recovery System (PRRS) Simulations, 28th International Conference on Incineration and Thermal Treatment Technologies, Cincinnati, OH, May 18-21, 2009.
24. **Lakshminarayana Rao** and Richard J. Munz Effect of Microstructure of Cathodes on Arc Erosion and Arc Velocity of Cold Cathodes, Proceedings of International Symposium on Plasma Chemistry-18, Paper No. 111, Kyoto, Japan, 2007.
25. **M. P. L. N. Rao**, G. S. Gupta and A. K. Suri, Modeling of boron carbide manufacturing process. Proceedings of EMC 2003, European Metallurgical Conference. Hanover, Germany, 2003.

### Book Chapter

1. Rao Harsha., **Rao L.**, Haridas H., Manju D.K., Swetha S., Chanakya H. (2020) Design and Characterization of Cold Plasma Ozonator for Wastewater Treatment. In: Ghosh S., Saha P., Francesco Di M. (eds) Recent Trends in Wastewater Treatment and Water Resource Management. Springer, Singapore. [https://doi.org/10.1007/978-981-15-0706-9\\_16](https://doi.org/10.1007/978-981-15-0706-9_16)
2. Gupta G.S. and **M.P.L. Rao** Scale up of Carbide Production. A book chapter in a titled book 'Scale-up in Metallurgy'. Published by ProcessEng Engineering GmbH (2010). ISBN: 3902655100. (All copyright reserved to the publisher).

### Patents Granted/Filed

1. **Lakshminarayana Rao**, Anand M Shivapuji and Dasappa S. Achieving anti-microbial property of plasma activated water on near neutral pH conditions. MS-CST-2018-082, PD033948IN-SC
2. **Lakshminarayana Rao**, Mohan Kumar M S, Chanakya H N, Shruthi T and Prasad A. A natural product-based formulation and a process to suppress foaming in flowing water bodies
3. **Lakshminarayana Rao**, Punith N, Ashish Singh, and Dipshikha C. A process and a setup to generate near neutral pH, highly potent plasma activated water for surface hygiene and wound healing applications
4. G S Gupta, Prince Raj, **M. P. L. N. Rao** and Rakesh Kumar. An optimized method for production of silicon carbide. MS-MAT-2018-081, PA- 201941052357
5. P. Carabin and **Lakshminarayana Rao**. Steam plasma arc hydrolysis of ozone depleting substances. US8716546 B2
6. P. Carabin and **Lakshminarayana Rao**. Steam plasma arc hydrolysis of ozone depleting substances. US8961887 B2

7. P. Carabin and **Lakshminarayana Rao**. Steam plasma arc hydrolysis of ozone depleting substances. US9506648 B2
8. P. Carabin and **Lakshminarayana Rao**. Steam plasma arc hydrolysis of ozone depleting substances. US9562684 B2
9. **Lakshminarayana Mydala Prahlada Rao**, Jocelyn Remillard, Pierre Carabin. High power dc non transferred steam plasma torch system. EP 2957152 A1
10. **Lakshminarayana Rao**, Pierre Carabin, Jean-Rene Gagnon, Bill Kreklewetz. Plasma fired steam generator system. CA 2924135 A1
11. **Lakshminarayana Rao** and Others. Method of treating surface with Activated Water and a Surfactant. EP 15189593.