**Name** : S. SARAVANAMURUGAN
**Qualification** : Ph. D. Chemistry (2005)
M. Phil. Chemistry (2001)
M. Sc. Chemistry (2000)
B. Sc. Chemistry (1998)
**Date of Joining** : 14 July 2016 (AN)
**Designation** : Scientist - E
**Discipline** : Chemistry

Email: saravana@ciab.res.in
Tel. No.:0091-1724990218

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## Major Research Accomplishment

Papers published in renowned scientific journals such as **Science** and **JACS**
Technology related to methyl lactate production from sugars transferred

## Previous Research Profile:

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|---|---|
| Jan. 2015- Jan.2018 | **Visiting Professor**, Guizhou University, RP China. |
| Dec 2013 - June 2016 | **Senior Researcher**<br>Centre for Catalysis and Sustainable Chemistry (CSC), Department of Chemistry, Technical University of Denmark (DTU), Denmark. |
| Sep. 2013 - Nov 2013 | **Research Chemist,** Haldor Topsøe, Denmark. |
| Jan. 2010 - Aug. 2013 | **Senior Researcher,** CSC, Department of Chemistry, DTU, Denmark. |
| Jan. 2008 - Dec 2009 | **Postdoctoral Fellow,** CSC and Centre for Sustainable and Green Chemistry, Department of Chemistry, DTU, Denmark. |
| Sep. 2006 - Oct. 2007 | **Postdoctoral Fellow,** Department of Chemistry, Inha University, South Korea. |
| June 2005 - May 2006 | **Research Scientist**, Department of Chemistry, KAIST, South Korea. |
| Oct. 2004 - Dec. 2004 | **DST-DAAD Fellow**, University of Kaiserslautern, Germany. |
| May 2001 - May 2004 | **Project Fellow**, Anna University, Chennai, India. |

## Current Responsibility at CIAB:

Valorisation of agro residues to high-value downstream biochemicals with chemocatalysts.

## Areas of Specialization:

Valorisation of Lignocellulosic Biomass to Chemicals and Fuels, Synthesis and Functionalization of Porous Materials, Synthesis of nano-sized bimetallic catalysts, Functionalised Ionic Liquids for $CO_2$ Capture, Functionalised Ionic liquids for Sugar Transformations.

## Award/Recognition

- ✓ DST-DAAD Fellow (2004)
- ✓ Early Career Research Award (2017)

**Publications: 46**; **Citations:** >1600**; H-Index:** 18; **Patents (filed/granted):** 8

**Peer Reviewed Publications**

1. H. Li, T. Yang, A. Riisager, **S. Saravanamurugan**,* and S.Yang, 'Chemoselective synthesis of dithioacetals from bio-aldehydes with zeolites under ambient and solvent-free conditions,' ChemCatChem, Accepted (2017) *(IF = 4.72)*.
2. H. Li, X. Liu, T. Yang, W. Zhao, **S. Saravanamurugan,** and S.Yang, 'Porous zirconium-furandicarboxylate microspheres for efficient redox conversion of biofuranics,' ChemSusChem, Accepted (2017) *(IF = 7.12)*.
3. Z. Wang, H. Li, S. Yang, and **S. Saravanamurugan,*** 'Conversion of sugars to 5-hydroxymethylfurfural with porous zirconium phenylphosphonate catalyst,' Adv. Porous Mater. Accepted (2017).
4. J. He, T. Yang, S. Yang, H. Li and **S. Saravanamurugan**,* 'Zr/Ti-catalyzed efficient synthesis of fuel additive $\gamma$-valerolactone from bio-based ethyl levulinate,' Journal of Energy and Environmental Sustainability, 2 (2017) 49.
5. **S. Saravanamurugan**, S. Meier, E. Taarning and A. Riisager, 'Mechanism and stereoselectivity of zeolite-catalysed sugar isomerisation in alcohols,' ChemComm, 52 (2016) 12773. *(IF = 6.57)*
6. H.Li, S. Yang, A Riisager, A. Pandey, R.S. Sangwan, **S. Saravanamurugan**,* R. Luque, 'Zeolite and zeotype-catalysed transformation of biofuranic compounds,' Green Chem., 18 (2016) 5701. *(IF = 8.51)*
7. H. Li, J. He, A. Riisager, **S. Saravanamurugan**,* B. Song and S.Yang, 'Acid-base bifunctional N-alkylphosphate nanohybrid for efficient hydrogen transfer of biomass-derived carboxides,' ACS Catalysis, 6 (2016) 7722-7727. *(IF = 9.31)*
8. **S. Saravanamurugan**, S. Meier, E. Taarning and A. Riisager, 'Combined function of Brønsted and Lewis acidity in the zeolite-catalysed isomerisation of glucose to fructose in alcohols,' ChemCatChem, 8 (2016) 3107. *(IF = 4.72)*
9. S. Tolborg, S. Meier, **S. Saravanamurugan**, P. Fristrup, E. Taarning and I. Sadaba, 'Shape-selective valorization of biomass-derived glycolaldehyde using tin-containing zeolites,' ChemSusChem, 9 (2016), 3054. *(IF = 7.12) (Chosen as Very Important Paper and Highlighted in Cover Page)*
10. Z. Gui, W. Cao, **S. Saravanamurugan**, A. Riisager, L. Chen and Z. Qi, 'Efficient Aerobic Oxidation of 5-Hydroxymethylfurfural in Aqueous Media with Au-Pd Supported on Zinc Hydroxycarbonate,' ChemCatChem, 8 (2016) 3636. *(IF = 4.72)*
11. Z. Gui, N. Zahrtmanna, **S. Saravanamurugan**, I. Reyero, Z. Qi, M. A. Banares, Anders Riisager, E. J. Garcia-Suarez, 'Brønsted acid ionic liquids (BAILs) as efficient and recyclable catalysts in the conversion of glycerol to solketal at room temperature,' ChemistrySelect, 1 (2016) 5869.
12. S. Tolborg, S. Meier, I. Sadaba, S. G. Elliot, S. K. Kristensen, **S. Saravanamurugan**, A. Riisager, P. Fristrup, T. Skrydstrup and E. Taarning, 'Tin-containing silicates: Identification of a glycolytic pathway via 3-deoxyglucosone,' **Green Chem.**, 18 (2016) 3360. *(IF = 8.51)*
13. H. Li, **S. Saravanamurugan**, S.Yang, A. Riisager, 'Direct transformation of carbohydrates to the biofuel 5-ethoxymethylfurfural by solid acid catalysts,' **Green Chem.**, 18 (2016) 726. *(IF = 8.51)*
14. H. Li, **S. Saravanamurugan**, S.Yang, A. Riisager, 'Catalytic alkylation of 2-methylfuran with formalin over supported acidic ionic liquids,' ACS Sustainable Chem. Eng., 3 (2015) 3274. *(IF = 5.27)*
15. M. Paniagua, **S. Saravanamurugan**, M. Melián-Rodríguez, J. Melero, A. Riisager, 'Xylose isomerisation with zeolites in two-step alcohol-water process,'**ChemSusChem**, 8 (2015) 1088. *(IF = 7.12)*
16. M. Melián-Rodríguez, **S. Saravanamurugan**, S. Kegnæs and A. Riisager, 'Aerobic oxidation of veratryl alcohol to veratraldehyde with heterogeneous ruthenium catalysts,' Top. Catal., 58 (2015) 1036. *(IF = 2.36)*

17. R. Poreddy, **S. Saravanamurugan**, A. Riisager, 'Highly selective liquid-phase benzylation of solid-acid zeolite catalysts' Top. Catal., 58 (2015) 1053. *(IF = 2.36)*
18. H. Li, R. Kotni, Q. Zhang, **S. Saravanamurugan** and S.Yang, 'Chemoselective oxidation of bio-glycerol with nano-sized metal catalysts,' Mini. Rev. Org. Chem., 12 (2015) 162. *(IF = 1.04)*
19. **S. Saravanamurugan** and A. Riisager, 'Zeolite-catalysed isomerisation of tetroses in aqueous medium,' Catal. Sci. Technol., 4 (2014) 3186. (*IF = 5.29)*
20. H. Li, K. S. Govinda, R. Kotni, **S. Saravanamurugan**, A. Riisager, S.Yang, 'Direct catalytic transformation of carbohydrates into 5-ethoxymethylfurfural with acid–base bifunctional hybrid nanospheres,' Energy Convers. Manage., 88 (2014) 1245 (*IF = 4.80)*
21. J. M. Rubio-Caballero, **S. Saraavanamurugan**, P. Maireles-Torres, A. Riisager, 'Acetalization of furfural with zeolites under benign reaction conditions,' Catal. Today, 234 (2014) 233. *(IF = 4.31)*
22. **S. Saravanamurugan**, A.J. Kunov-kruse , R. Fehrmann and A. Riisager, 'Amine functionalised amino acid ionic liquids as efficient and high-capacity absorbents for $CO_2$,' **ChemSusChem**, 7 (2014) 897. *(IF = 7.12)*
23. A. J. Kunov-Kruse, A. Riisager, **S. Saravanamurugan**, Rolf W. Berg, S. B. Kristensen, and R. Fehrmann, 'Revisiting the Brønsted acid catalysed hydrolysis kinetics of polymeric carbohydrates in ionic liquids by in-situ ATR-FTIR spectroscopy,' **Green Chem.**, 15 (2013) 2843. *(IF=8.51)*
24. **S. Saravanamurugan** and A. Riisager, 'Zeolite catalysed transformation of carbohydrates to alkyl levulinates,' ChemCatChem, 5 (2013) 1754. *(IF=4.72)*
25. **S. Saravanamurugan**, M. Paniagua, J. Melero, A. Riisager, 'Efficient isomerization of glucose to fructose over zeolites in consecutive reactions in alcohol and aqueous media,' ***J. Am. Chem. Soc.**, 135 (2013) 5246.* (IF = 13.04)
26. **S. Saravanamurugan** and A. Riisager, 'Brønsted Acid Ionic Liquid Catalyzed Formation of Pyruvaldehyde dimethylacetal from Triose Sugars,' Catal. Today 200 (2013) 94. *(IF=4.31)*
27. **S. Saravanamurugan,** A. Riisager and R. Fehrmann, 'Synthesis and characterisation of ammonium-, pyridinium- and pyrrolidinium- based sulfonamido functionalised ionic liquids,' Syn. Commun., 42 (2012) 3383. *(IF=1.06)*
28. M.S. Holm, Y. Pagan, **S. Saravanamurugan**, A. Riisager, J.A. Dumesic and E. Taarning, 'Sn-beta catalysed conversion of hemicellulosic sugars,' **Green Chem.**, 14 (2012) 702. *(IF=8.51)*
29. **S. Saravanamurugan** and A.Riisager, 'Solid acid catalyzed formation of ethyl levulinate and ethyl glucopyranoside from mono- and disaccharides,' Catal. Commun. 17 (2012) 71. *(IF=3.39)* ***(one of the most cited 2011-2012 articles in Catalysis Communications)***
30. **S. Saravanamurugan**, O.N.V. Buu and A. Riisager, 'Conversion of Mono- and Disaccharides to Ethyl Levulinate and Ethyl Pyranoside with Sulfonic Acid Functionalized Ionic Liquids,' **ChemSusChem**., 4 (2011) 723. *(IF=7.12)*
31. J-B. Koo, N. Jiang, **S. Saravanamurugan**, M. Bejblova, Z. Musilova, J. Cejka, S-E. Park, 'Direct synthesis of carbon-templating mesoporous ZSM-5 using microwave heating,' **J. Catal.**, 276 (2010) 327. ***(One of the Top 25 Hottest articles in Journal of Catalysis, ScienceDirect, Oct. to Dec. 2010).*** *(IF=7.35)*
32. M. S. Holm, **S. Saravanamurugan**, E. Taarning, 'Conversion of sugars to lactic acid derivatives using heterogeneous zeotype catalysts,' **Science**, 328 (2010) 602. ***(first and second authors equally contributed)*** *(IF=34.66)*
33. **S. Saravanamurugan**, S. Kegnæs, J. Due-Hansen, T.A. Gretasdottir, A. Riisager, R. Fehrmann, 'Selective gas absorption by ionic liquids,' ECS Transactions, 33 (2010) 117.
34. Ryan M West, M. S. Holm, **S. Saravanamurugan**, J. Xiong, Z. Beversdorf, E. Taarning, C.H. Christensen, 'Zeolite H-USY for the production of lactic acid and methyl lactate from C3-sugars,' **J. Catal.**, 269 (2010) 122. *(IF=7.35)*

35. U. Mentzel, **S. Saravanamurugan**, S. Hruby, C.H. Christensen, M. S. Holm, 'High yield of liquid range olefins obtained by converting i-propanol over zeolite ZSM-5,' **J. Am. Chem. Soc.,** 131 (2009) 17009. *(IF=13.04)*
36. E. Taarning, **S. Saravanamurugan**, M. S. Holm, J. Xiong, R. M. West, C. H. Christensen, 'Zeolite-catalysed isomerisation of triose sugars,' **ChemSusChem.** 2 (2009) 625. *(IF=7.12)*
37. **S. Saravanamurugan,** E. A. Prasetyanto, Sujandi and S-E. Park, 'Short channeled amino functionalised SBA-15 catalysts for the liquid phase reaction between 2'-hydroxyacetophenone and benzaldehyde,' Stud. Sur. Sci. Catal. 174 (2008) 1271.
38. **S. Saravanamurugan,** Sujandi, E. A. Prasetyanto and S-E. Park, 'Liquid-phase reaction of 2'-hydroxyacetophenone and benzaldehyde over $SO_3H$-SBA-15 catalysts: Influence of microwave and thermal effects,' Micropor. Mesopor. Mater. 112 (2008) 97. *(IF=3.35)*
39. **S. Saravanamurugan,** Sujandi, Dae Soo Han, J-B Koo and S-E. Park, 'Transesterification reactions over morphology controlled amino functionalized SBA-15,' Catal. Commun. 9 (2008) 158. *(IF=3.39)*
40. G.Satish Kumar, **S. Saravanamurugan**, M. Palanichamy, M. Hartmann and V. Murugesan '**Synthesis, characterisation and catalytic performance of HMCM-22 of different silica to alumina ratios,'** J. Mol. Cat. A: Chemical 272 (2007) 38. ***(One of the Top 25 Hottest articles in J. Mol. Catal. A. Chem., ScienceDirect, April to June 2007)*** *(IF=3.96)*
41. **S. Saravanamurugan**, M. Palanichamy, M. Hartmann and V. Murugesan, 'Knoevenagel condensation over solid acid catalysts in liquid phase under solvent free condition,' Appl. Catl. A: General 298 (2006) 8. *(IF=4.01)*
42. **S. Saravanamurugan**, M. Palanichamy, B. Arabindoo and V. Murugesan 'Solvent free synthesis of chalcone and flavanone over zinc oxide supported metal oxide catalysts,' Catal. Commun. 6 (2005) 399. ***(One of the Top 25 Hottest articles in Catalysis Communications, ScienceDirect, July to Sep. 2005)*** *(IF=3.39)*
43. **S. Saravanamurugan**, M. Palanichamy and V. Murugesan **'**Oxyfunctionalisation of toluene with activated *t*-butyl hydroperoxide,' Appl. Catal. A: General, 273 (2004) 143. *(IF=4.01)*
44. **S. Saravanamurugan**, M. Palanichamy, B. Arabindoo and V. Murugesan, 'Liquid phase reaction of 2′-hydroxyacetophenone and benzaldehyde over ZSM-5 catalysts,' J. Mol. Catal. A: Chemical, 218 (2004) 101. *(IF=3.96)*
45. A. Vinu, K. Ariga, **S. Saravanamurugan**, M. Hartmann and V. Murugesan, 'Synthesis of highly acidic and well ordered MgAl-MCM-41 and its catalytic performance on the isopropylation of *m*-cresol,' Micropor. and Mesopor. Mater., 76 (2004) 91. *(IF=3.35)*
46. K. Shanmugapriya, **S. Saravanamurugan**, M. Palanichamy, B. Arabindoo and V.Murugesan, 'Alkylation and acylation of phenol with methyl acetate,' J. Mol. Catal. A: Chemical, 223 (2004) 177. *(IF=3.96)*

**Patents**

1. E. Taarning, **S. Saravanamurugan**, H. M. Spangsberg, (2009), 'Zeolite catalysed preparation of α- hydroxycarboxylic compounds and esters thereof,' Patent granted. US2010012196, EP 2184270 B1, CN 200910253083
2. **S. Saravanamurugan**, A. Riisager, (2012) 'Conversion of carbohydrates to levulinic acid esters,' Patent No. EP 2880009-A1; US 9290429 B2.
3. **S. Saravanamurugan**, A. Riisager, (2012), 'Isomerisation C4-C6 aldoses with zeolites,' Patent No. WO 2014033311-A1; EP2892907-B1; US 20150232498.
4. **S. Saravanamurugan**, A. Riisager, R. Fehrmann, (2014), '$CO_2$ chemisorption by functionalised amino acid derivatives,' Patent No. WO2015107060-A1.
5. H. Kolding, **S. Saravanamurugan**, A. Riisager, R. Fehrmann, (2012), '$CO_2$ sorption by supported amino acid ionic liquids,' Patent No. WO 2014009533-A1 (2014); CA 2878103-A1 (2014); US 20150196895 (2015); CN 104470633 A (2015).
6. **S. Saravanamurugan,** S. Z. Irantzu, E. Taarning, M. S. Holm, 'Crystalline microporous material mediated conversion of C1- 3 to C4 oxygenate compounds,' Application No.: WO 2015193461.

7. **S. Saravanamurugan**, K.G. Santosh, A. Riisager, 'A process for hydrogynolysis of alpha-hydroxyesters or acids using a heterogeneous catalyst,' EP patent filed (2015).
8. **S.Saravanamurugan** and A. Riisager, 'Preparation of levulinic acid esters with zeolites from fructose,' US patent filed.

**Detailed Research Accomplishments:**

***Current Research Activities – Transformation of lignocellulosic biomass to chemicals and fuels:***

- **Sugar Isomerisation and its direct conversion to biofuels:**

  **Objectives:** The goal of this project is to develop a non-enzymatic approach for the interconversion of glucose to fructose - as it has potential application in making High Fructose Corn Syrup (HFCS)- and to produce biofuel such as ethyl levulinate and 5-ethoxmethylfurfural (EMF).

  **Major Achievements**

  - Developed a new reaction protocol where fructose can be produced from glucose in high yield (>50 %) in one-pot two-step using zeolite as catalysts.
  - Developed a reaction protocol to make ethyl levulinate (~50%) directly from glucose and other carbohydrates using zeolites-containing Brønsted and Lewis acid sites.
  - Developed a method to produce ~50% and 70% EMF, biofuel, from glucose and fructose, respectively, employing nonporous zeolites as catalysts.
  - Outcome results published in high impact journals such as JACS, Green Chemistry, ChemSusChem and **2 patents.**

- **Hydrogenolysis of alpha-hydroxyester:**

  **Objectives:** The ambition of this project is to investigate mixed oxide catalysts for the selective hydrogenolysis of alpha-hydroxyesters to propionates

  **Major Achievements**

  - Developed nano-sized mixed metal oxide catalysts that can selectively convert lactates to propionates above 70%.
  - This invention has been filed for **a patent**.

- **Sugars to lactic acid (Milk acid):**

  **Objectives:** The ambition of this project is to study and develop an alternative heterogeneous process to the biochemical process- fermentation of glucose to lactic acid- as lactic acid is one of the bio-platform chemicals and potential precursor for making bio-degradable plastics.

  **Major Achievements**

  - Invented a process to make methyl lactate, precursor for bioplastics, from sugars in high yields (~ 70%) using solid Lewis acid-containing zeolites.
  - The accomplished results published in a reputed journal **Science**.
  - This achievement has been highlighted in the following research newspapers: Chemical and Engineering News, Chemistry World, Videnskab.dk, and Ingenioren.
  - **Technology Transferred** to Danish company Haldor Topsøe in 2008/2009.

- **Carbon Capture using ionic liquids:**

  **Objectives:** The aim of this project is to find out suitable functionalised ionic liquids as reversible absorbents with enhanced $CO_2$ absorption capacity, as current flue gas cleaning technology suffers a lot with traditional aqueous solution of monoethanolamine (MEA).

  **Major Achievements**

  - Achieved to synthesise amino acid functionalised ionic liquids which can uptake higher than two moles of $CO_2$ per mole of ionic liquids. This is the highest $CO_2$ absorption capacity that has been disclosed in the literature at that point.
  - This invention led to two patents and the results published in a high impact journal ChemSusChem.

- **Microwave-assisted synthesis and catalytic application of micro- and mesoporous materials:**

  **Objectives:** The major purpose of this project is to find out the influence of microwave compared to conventional method for the synthesis of microporous and mesoporous materials.

  **Major Achievements**

  - Morphology of the functionalised SBA-15 materials can be controlled by microwave treatment
  - Narrow mesopore size distribution of H-ZSM-5 was achieved using microwave over conventional heating treatment

***Research Challenges and Future Direction:***

- ***Lignin valorisation***

  ***Aim:*** To develop facile and efficient methods for the isolation of lignin from woody biomass and to improve the yield of similar aromatic compounds from the isolated lignin, as the lignin is the one of major sources for aromatic compounds that can substitute fossil-based aromatic compounds.

- ***Direct conversion of cellulose/hemicellulose to chemicals and fuels***

  One of the major challenges in woody biomass conversion is to directly transform cellulose to the targeted chemicals, for example, lactic acid, as cellulose has very limited solubility in aqueous and most organic solvents that hampers the upgrading of cellulose conversion.

  ***Aim:*** To develop a chemo and integrated chemo-enzymatic process where cellulose can be hydrolysed to monomeric form of glucose at low temperature without significant amount of degradation, followed by chemo-catalytic, for example, nanoporous zeolites, conversion to the targeted products.

**Outreach-in news & Miscellaneous**

- ChemSusChem, 2009 article has been highlighted in Chemical and Engineering News in Science and Technology segment on 6th July, 2009.
- Science, 2010 article has been highlighted in the following research newspapers
  - Chemical and Engineering News, 'Methyl Lactate from Sugar, Catalytically' on 3rd May, 88 (18) 2010.
    Link: http://pubs.acs.org/isubscribe/journals/cen/88/i18/html/8818scic7.html
  - Chemistry World, 'Catalyst Challenges microbes' supremacy' on 29th April 2010.
    Link: http://www.rsc.org/chemistryworld/News/2010/April/29041003.asp
  - Videnskab dk, 'Danish researchers invent simple way for nature-friendly plastic' on 29th April 2010.
    Link:http://videnskab.dk/teknologi/danske-forskere-opfinder-nem-vej-til-naturvenlig-plastik
  - Ingenioren, 'Groundbreaking: Haldor Topsoe ready with an alternative to fermentation' on 29th April 2010.
    Link:http://ing.dk/artikel/108372-banebrydende-haldor-topsoee-klar-med-alternativ-til-fermentering
- Science article has been highlighted in article titled 'Synthetic Glycolysis', CHEMSUSCHEM, 3 (2010) 1237
- Science article has been highlighted in 'Sugars-sweet to eat but sweeter to make chemicals', Bulletin of the catalysis society of India –news brief, 2010.