

# Curriculum Vitae

## Dr. Sib Sankar Mal

Assistant Professor,  
Department of Chemistry, Science Block,  
National Institute of Technology (NIT-K),  
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## Education

- 10/2004 - 11/2008: **Doctor of Philosophy (Ph.D.)** at Jacobs University, Bremen, Germany,  
Research Group: Prof. Dr. Ulrich Kortz.  
Research Topic: *Synthesis and structural characterization with multiple analytical methods of Polyoxometalate Chemistry*
- 08/2001 - 08/2003: **Master of Science (M.Sc.)** at Indian Institute of Technology, Bombay, India,  
Research Topic: *Phosphorus Chemistry*
- 08/1998 - 08/2001: **Bachelor of Science (B.Sc.) in Chemistry**, Vidyasagar University, Kolkata.

## Professional Experience

- Since 11/2013: Assistant Professor at National Institute of Technology (NIT-K) at Surathkal, India.
- 11/2011 - 10/2013: **Alexander von Humboldt Postdoctoral Research Fellow** at Universität Hamburg,  
Research Group: Prof. Dr. Peter Burger  
Research Topic: *Redox Active Transition Metal Containing Ionic Liquids for use in Flow Batteries.*
- 01/2009 - 02/2011: **Postdoctoral Fellow** at Center for Catalysis Research and Innovation (CCRI), University of Ottawa, Ottawa, Ontario, Canada.  
Research Group: Prof. Dr. R.T. Baker  
Research Topics: *1. Development of Amine-Borane Fuels. 2. New Base Metal heterogeneous Catalysts for Sodium Borohydride hydrolysis.*

## Courses Taught

M.Sc : CY 705: Spectroscopy (Theory)  
: CY 706: Inorganic Chemistry Practical-I (Laboratory)  
: CY 861: Organometallic Chemistry (Theory)  
: CY 862: Bioinorganic Chemistry (Theory)  
: CY 863: Novel Inorganic Compounds (Theory)

B.Tech. : CY 111: Chemistry Theory  
: CY110: Chemistry Lab  
: CY305: Inorganic and Physical Chemistry (Theory)

## Languages

Bengali : Mother Tongue  
Hindi : Fluent in Spoken and written  
English : Fluent in Spoken and written  
German : Basic Knowledge

## Administrative Duties

1. Faculty advisor of first year Post-graduate students.
2. Secretary of Department of Undergraduate Committee (DUGC).
3. Member of Department of Post-graduate Committee (DPGC).
4. Member of Department of Research Proposal Committee (DRPC).
5. Secretary of Departmental purchase committee.
6. Member of course Time-table committee.

## Supervised Students

Completed: 6 (Master student), 1 (Summer Student)

On Going: 1 (PhD)

## Publications List

**Total Citations =1423, *h* index = 23 *i* 10-index = 28**

1. Structural and optical characterization of the starch granules due to the effect of  $\alpha$ -amylase  
Suchitta Umashankar, Nirmal Mazumder, Ram Mahato, ***Sib Sankar Mal***, K.K.Mahato,  
**Submitted**
2. Retention of high dielectric constant sodium beta alumina in solution combustion: role of  
aluminum ions complexation with urea, glycine and citric acid  
Bikesh Gupta, Pavan Pujar, **Sib Sankar Mal**, Dipti Gupta, Saumen Mandal, ***Submitted***

3. *Porous base-metal catalysts for alkaline-free sodium borohydride hydrolysis* Mehdi Mostajeran, Vanessa Prévot, **Sib Sankar Mal**, Emily Mattiussi, Boyd R. Davis, R. Tom Baker, *International journal of hydrogen energy*, **2017**, 42, 20092-20102.
4. *A Liquid Derivative of Phosphotungstic Acid as Catalyst for Benzyl Alcohol Oxidation in Water: Facile Separation and Stability of Benzaldehyde at Room Temperature* Rama Ranjan Bhattacharjee, Thangamani Suppan, **Sib Sankar Mal**, *ChemistrySelect*, **2017**, 2, 4368 – 4375.
5. *Dependence of the  $0.5x(2e^2/h)$  conductance plateau on the aspect ratio of InAs quantum point contacts with in-plane side gates*  
Partha Pratim Das, Alex Jones, Marc Cahay, S. Kalita, **Sib Sankar Mal**, N. Sterin, T. Yadunath, M. Advaita, Steve Herbert, *Journal of Applied Physics*, **2017**, 121, 083901.
6. *Characterization of Pt<sup>IV</sup>-containing Polyoxometalates by High-Resolution Solid-State <sup>195</sup>Pt and <sup>51</sup>V NMR Spectroscopy*  
S. Dugar, Nataliya V. Izarova, **Sib Sankar Mal**, Riqiang Fu, H. -C. Joo, Uk Lee, Naresh S. Dalal, Michael T. Pope, Geoff B. Jameson, Ulrich Kortz, *New J. Chem.*, **2016**, 40, 923-927.
7. *Electrocatalysis by crown-type polyoxometalates multi-substituted by transition metal ions: Comparative study*  
Naseer Rashda, **Sib Sankar Mal**, Ulrich Kortz, Gordon Armstrong, Fathima Laffir, Calum Dickinson, Mikhail Vagin, Timothy McCormac, *Electrochem. Acta*, **2015**, 176, 1248-1255.
8. *Redox, surface and electrocatalytic properties of layer-by-layer films based upon Fe(III)-substituted crown polyoxometalate  $[P_8W_{48}O_{184}Fe_{16}(OH)_{28}(H_2O)_4]^{20-}$*   
Rashda Naseera, **Sib Sankar Mal**, Masooma Ibrahim, Ulrich Kortz, Gordon Armstrong, Fathima Laffir, Calum Dickinson, Mikhail Vagin, Timothy McCormac, *Electrochem. Acta*, **2014**, 134, 450-458. (Times Cited = 5)
9. *Tetraalkylphosphonium Decavanadates: Synthesis, Structure and Solution Properties*  
**Sib Sankar Mal**, Oliver Tröppner, Ivana Ivanović-Burmazović, Peter Burger, *Eur. J. Inorg. Chem.*, **2013**, 1960-1967. (Corresponding author, Times Cited = 2)
10. *Dendri-POM Hybrids Based on Keggin, Wells-Dawson, Preyssler and Venturello Polyanions and Their Catalytic Activity in Oxidation Reactions*  
Claire Jahier, **Sib Sankar Mal**, Ulrich Kortz, Sylvain Nlate, *Polyhedron*, **2013**, 57, 57-63. (Times Cited = 5)
11. *Redox Switching of Polyoxometalate-Methylene Blue based Layer-by-Layer Films*  
Nargis Anwar, Mikhail Vagin, Rashda Naseer, Shahzad Imar, Masooma Ibrahim, **Sib Sankar Mal**, Ulrich Kortz, Fathima Laffir, Timothy McCormac, *Langmuir*, **2012**, 28, 5480-5488. (Times Cited = 13)

12. *Reactive Zr<sup>IV</sup> and Hf<sup>IV</sup> Butterfly Peroxide on Polyoxometalate Surfaces: Bridging the gap between Homogeneous and Heterogeneous Catalysis*  
 Mauro Carraro, Nadeen H. Nsouli, Holger Oelrich, Andrea Sartorel, Antonio Sorarú, **Sib Sankar Mal**, Gianfranco Scorrano, Lorenz Walder, Ulrich Kortz, Marcella Bonchio, *Chem. Eur. J.*, **2011**, *17*, 8371-8378. (Times Cited = 45)
13. *Alpha and Beta Isomers of Tetrahafnium(IV) Containing Decatungstosilicates, [Hf(OH)<sub>6</sub>(CH<sub>3</sub>COO)<sub>2</sub>(x-SiW<sub>10</sub>O<sub>37</sub>)<sub>2</sub>]<sup>12-</sup> (x = α, β)*  
 Awatef S. Assran, **Sib Sankar Mal**, Natalya V. Izarova, Borislav Milev, Abhishek Banerjee, Andreas Suchopar, Masahiro Sadakane and Ulrich Kortz, *Dalton Trans.*, **2011**, *40*, 2920-2925. (Times Cited: 11)
14. *Metal-Catalyzed Dehydrogenation of Amine-Borane Fuel Blends*  
**Sib Sankar Mal**, Frances H. Stephens, R. Tom Baker, *Chem. Commun.*, **2011**, *47*, 2922-2924. (Times Cited = 45)
15. *Yttrium(III)-containing tungstoantimonate(III) stabilized by capping, tetrahedral WO<sub>4</sub><sup>2-</sup> unit, [Y(α-SbW<sub>9</sub>O<sub>31</sub>(OH)<sub>2</sub>)(CH<sub>3</sub>COO)(H<sub>2</sub>O)]<sub>3</sub>(WO<sub>4</sub>)<sup>17-</sup>*  
 Masooma Ibrahim, **Sib Sankar Mal**, Bassem S. Bassil, Abhishek Banerjee, Ulrich Kortz, *Inorg. Chem.*, **2011**, *50*, 956-960. (Times Cited = 24)
16. *Yttrium-containing Head-on Complexes of Silico- and Germanotungstate: Synthesis, Structure and Solution Properties*  
 Firasat Hussain, Alois Degonda, Stefan Sandriesser, Thomas Fox, **Sib Sankar Mal**, Ulrich Kortz and Greta R. Patzke, *Inorg. Chim. Acta*, **2010**, *363*, 4324-4328. (Times Cited = 7)
17. *Hexa-zirconium/hafnium-containing Tungstoarsenates(III) and their Oxidation Catalysis Properties*  
 Ghada Al-Kadamany<sup>‡</sup>, **Sib Sankar Mal**<sup>‡</sup>, Borislav Milev, Baira Donoevap, Raisa Maksimovskaya, Oxana A Kholdeeva, Ulrich Kortz, *Chem. Eur. J.*, **2010**, *16*, 11797-11800. (‡ - These authors contributed equally to this work, Times Cited = 21)
18. *Unique Supramolecular Assembly of Wheel-Shaped Nanoscale Polyanions with a Hydrophobic Core*  
 Jie Zhang, Tianbo Liu, **Sib Sankar Mal**, Ulrich Kortz, *Eur. J. Inorg. Chem.*, **2010**, 3195-3200. (Times Cited = 8)
19. *Cobalt, Manganese, Nickel, and Vanadium Derivatives of the Cyclic 48-Tungsto-8-Phosphate [H<sub>7</sub>P<sub>8</sub>W<sub>48</sub>O<sub>184</sub>]<sup>33-</sup>*

- Bassem S. Bassil, Masooma Ibrahim, **Sib Sankar Mal**, Andreas Suchopar, Rosa Ngo Biboum, Bineta Keita, Louis Nadjo, Saritha Nellutla, Johan van Tol, Naresh S. Dalal, Ulrich Kortz, *Inorg. Chem.*, **2010**, 49, 4949-4959. (Times Cited = 37)
20. *Dendritic Zirconium-Peroxo Tungstosilicate Hybrids: Synthesis, Characterization and Use as Recoverable and Reusable Sulfide Oxidation Catalysts*  
 Claire Jahier, **Sib Sankar Mal**, Ulrich Kortz and Sylvain Nlate, *Eur. J. Inorg. Chem.*, **2010**, 1559-1566. (Times Cited = 19)
21. *Peroxo-Zr/Hf Containing Undecatungstosilicates and -Germanates*  
**Sib Sankar Mal**<sup>1</sup>, Nadeen H. Nsouli<sup>1</sup>, Michael H. Dickman, Mauro Carraro, Andrea Sartorel, Gianfranco Scorrano, Marcella Bonchio and Ulrich Kortz, *Inorg. Chem.*, **2010**, 49, 7-9. (<sup>1</sup> - These authors contributed equally to this work, Times Cited = 50)
22. *Synthesis and Crystal Structures of dmsO-Coordinated Tungstoantimonates(III) and Tungstobismutates(III)*  
 Li-Hua Bi, Guang-Feng Hou, Ya-Yan Bao, Bao Li, Li-Xin Wu, Zhong-Min Gao, Timothy McCormac, **Sib Sankar Mal**, Michael H. Dickman and Ulrich Kortz, *Eur. J. Inorg. Chem.*, **2009**, 5259-5266. (Times Cited = 9)
23. *The Wheel-Shaped Cu<sub>20</sub>-Tungstophosphate [Cu<sub>20</sub>X(OH)<sub>24</sub>(H<sub>2</sub>O)<sub>12</sub>(P<sub>8</sub>W<sub>48</sub>O<sub>184</sub>)]<sup>25-</sup> Ion (X = Cl, Br, I) and the Role of the Halide Guest*  
**Sib Sankar Mal**, Bassem S. Bassil, Ulrich Kortz, Saritha Nellutla, Johan van Tol, Naresh S. Dalal, Jorge A. Fernández, Xavier López, Josep M. Poblet, Rosa Ngo Biboum, Bineta Keita, *Inorg. Chem.*, **2009**, 48, 11636-11645. (Times Cited = 36)
24. *Preparation and Characterization of Langmuir-Blodgett films of Wheel-shaped Cu-20 Tungstophosphate and DODA by Two Different Strategies*  
 Ya-Yan Bao, Li-Hua Bi, Li-Xin Wu, **Sib Sankar Mal**, Ulrich Kortz, *Langmuir*, **2009**, 25, 13000-13006. (Times Cited = 35)
25. *Heterogeneous Wheel-shaped Cu<sub>20</sub>-tungstophosphate ([Cu<sub>20</sub>Cl(OH)<sub>24</sub>(H<sub>2</sub>O)<sub>12</sub>(P<sub>8</sub>W<sub>48</sub>O<sub>184</sub>)]<sup>25-</sup>): Catalyst for Solvent-free Aerobic Oxidation of n-Hexadecane*  
 Lifang Chen, Juncheng Hu, **Sib Sankar Mal**, Ulrich Kortz, Helge Jaensch, Georges Mathys, Ryan M. Richards, *Chem. Eur. J.*, **2009**, 15, 7490-7497. (Times Cited = 22)
26. *Actinide Polyoxometalates: Incorporation of Uranyl-Peroxo in U-Shaped 36-Tungsto-8-Phosphate*  
**Sib Sankar Mal**, Michael H. Dickman, Ulrich Kortz, *Chem. Eur. J.*, **2008**, 14, 9851-9855. (Times Cited = 44)
27. *Cyclic Ti<sub>9</sub>-Keggin Trimers with Tetrahedral (PO<sub>4</sub>) or Octahedral (TiO<sub>6</sub>) Capping Groups*

- Ghada Al-Kadamany, Firasat Hussain, **Sib Sankar Mal**, Michael H. Dickman, Nathalie Leclerc-Laronze, Jérôme Marrot, Emmanuel Cadot, Ulrich Kortz, *Inorg. Chem.*, **2008**, *47*, 8574-8576. (**Times Cited = 21**)
28. *Synthesis and Structural Characterization of the Yttrium-containing Isopolytungstate  $[YW_{10}O_{36}]^{9-}$*   
 Maria Barsukova, Michael H. Dickman, Elena Visser, **Sib Sankar Mal**, Ulrich Kortz, *Z. Anorg. Allg. Chem.*, **2008**, *634*, 2423-2427. (**Times Cited = 9**)
29. *6-Peroxo-6-Zirconium Crown and its Hafnium-Analogue Embedded in a Triangular Polyanion:  $[M_6(O_2)_6(OH)_6(\gamma-SiW_{10}O_{36})_3]^{18-}$  ( $M = Zr, Hf$ )*  
 Bassem S. Bassil, **Sib Sankar Mal**, Michael H. Dickman, Ulrich Kortz, Holger Oelrich, Lorenz Walder, *J. Am. Chem. Soc.*, **2008**, *130*, 6696-6697. (**Times Cited = 83**)
30. *Mixed-Valence 24-Vanadophosphate Decorated with Six  $Ru^{II}(dmsO)_3$  Groups:  $[{Ru^{II}}_3(dmsO)_9PV^{V}_{11}V^{IV}Ru^{III}O_{37}(OH)_3]^{8-}$*   
 Li-Hua Bi, **Sib Sankar Mal**, Nadeen H. Nsouli, Michael H. Dickman, Ulrich Kortz, Saritha Nellutla, Naresh S. Dalal, Manuel Prinz, George Hofmann, Manfred Neumann, *J. Clust. Sci.*, **2008**, *19*, 259-273. (**Times Cited = 13**)
31. *Pulsed field Magnetization, Electron Spin Resonance, and Nuclear Spin-lattice Relaxation in the  $\{Cu_3\}$  Spin Triangle*  
 Kwang-Yong Choi, Naresh S. Dalal, Arneil P. Reyes, Philip L. Kuhns, **Sib Sankar Mal**, Ulrich Kortz, *Phys. Rev. B*, **2008**, *77*, 024406. (**Times Cited = 19**)
32. *Nucleation Process in the Cavity of a 48-tungstophosphate Wheel Resulting in a 16 Metal Center Iron-oxide Nanocluster*  
**Sib Sankar Mal**, Michael H. Dickman, Ulrich Kortz, Ana Maria Todea, Alice Merca, Hartmut Bögge, Thorsten Glaser, Achim Müller, Saritha Nellutla, Narpinder Kaur, Johan van Tol, Naresh S. Dalal, Bineta Keita, Louis Nadjjo, *Chem. Eur. J.*, **2008**, *14*, 1186-1195. (**VIP Article, Times Cited = 82**)
33. *Platinum-Containing Polyoxometalates*  
 Ulrich Kortz, Uk Lee, Hea-Chung Joo, Ki-Min Park, **Sib Sankar Mal**, Michael H. Dickman, G. B. Jameson, *Angew. Chem. Int. Ed.*, **2008**, *47*, 9383-9384. (**Times Cited = 17**)
34. *Facile Incorporation of Platinum(IV) into Polyoxometalate Frameworks: Preparation of  $[H_2Pt^{IV}V_9O_{28}]^{5-}$  and First Evidence of  $^{195}Pt$  NMR*  
 Uk Lee, Hea-Chung Joo, Ki-Min Park, **Sib Sankar Mal**, Ulrich Kortz, Bineta Keita, Louis Nadjjo, *Angew. Chem. Int. Ed.*, **2008**, *47*, 793-796. (**Times Cited = 57**)
35. *Two Iron-Containing Tungstogermanates:  $[K(H_2O)(\beta-Fe_2GeW_{10}O_{37}(OH))(\gamma-GeW_{10}O_{36})]^{12-}$  and  $[{\beta-Fe_2GeW_{10}O_{37}(OH)_2}]^{12-}$*

- Nadeen H. Nsouli, **Sib Sankar Mal**, Michael H. Dickman, Ulrich Kortz, Bineta Keita, Louis Nadjo, Juan M. Clemente-Juan, *Inorg. Chem.*, **2007**, *46*, 8763-8770. (Times Cited = 27)
36. *Organoruthenium Derivative of the Cyclic  $[H_7P_8W_{48}O_{184}]^{33-}$  Anion:  $[\{K(H_2O)\}_3\{Ru(p\text{-cymene})(H_2O)\}_4P_8W_{49}O_{186}(H_2O)_2]^{27-}$*   
**Sib Sankar Mal**, Nadeen H. Nsouli, Michael H. Dickman, Ulrich Kortz, *Dalton Trans.*, **2007**, 2627-2630. (With Inside Cover Picture, Times Cited = 55)
37. *Wheel-Shaped Polyoxotungstate  $[Cu_{20}Cl(OH)_{24}(H_2O)_{12}(P_8W_{48}O_{184})]^{25-}$  Macroanion Forms Supramolecular "Blackberry" Structure in Aqueous Solution*  
 Guang Liu, Tianbo Liu, **Sib Sankar Mal**, Ulrich Kortz, *J. Am. Chem. Soc.*, **2006**, *128*, 10103-10110 (Addition/Correction, **2007**, *129*, 2408-2408). (Times Cited = 97)
38. *STM/STS Observation of Polyoxoanions on HOPG Surfaces: The Wheel-shaped  $[Cu_{20}Cl(OH)_{24}(H_2O)_{12}(P_8W_{48}O_{184})]^{25-}$  and the Ball-shaped  $[\{Sn(CH_3)_2(H_2O)\}_2\{Sn(CH_3)_2\}_{12}(A-PW_9O_{34})_{12}]^{36-}$*   
 Mohammad S. Alam, V. Dremov, Paul Müller, Andrei V. Postnikov, **Sib Sankar Mal**, Firasat Hussain, Ulrich Kortz, *Inorg. Chem.*, **2006**, *45*, 2866-2872. (Times Cited = 36)
39. *The Wheel-Shaped  $Cu_{20}$ -Tungstophosphate  $[Cu_{20}Cl(OH)_{24}(H_2O)_{12}(P_8W_{48}O_{184})]^{25-}$ , Redox and Electrocatalytic Properties*  
 Darine Jabbour, Bineta Keita, Louis Nadjo, Ulrich Kortz, **Sib Sankar Mal**, *Electrochem. Commun.*, **2005**, *7*, 841-847. (Times Cited = 59)
40. *The Wheel-Shaped  $Cu_{20}$ -Tungstophosphate  $[Cu_{20}Cl(OH)_{24}(H_2O)_{12}(P_8W_{48}O_{184})]^{25-}$  Ion*  
**Sib Sankar Mal** and Ulrich Kortz, *Angew. Chem. Int. Ed.*, **2005**, *44*, 3777-3780. (Times Cited = 251)

### **Awards and Fellowships**

1. Recipient of **Alexander von Humboldt** Postdoctoral Fellow
2. Recipient of **DFG** Fellowship for the PhD programme.
3. Recipient of **Madhav Pandya** Scholarship from IIT Bombay.
4. Secured First Class in B.Sc. (Honors in Chemistry).
5. Recipient of GDCh Scholarship for '2nd EuCheMS Chemistry Congress' Program

## **Poster and Oral Presentations**

1. Oral presentation: *Recent Development of organic transformation reactions using polyoxometalates as a potential catalysts*, NITK Surathkal, ChemFlash Programme, November 04, 2016.
2. Oral presentation: *Synthesis and characterization of graphene oxide-polyoxometalate composite material for device applications*, **4th National Conference on Condensed Matter Physics and Applications**, Manipal University, Karnataka, INDIA, May 23-24, 2016
3. Poster presentation: *Variational Calculation of Exciton Energy in Spherical Quantum Well*, **4th National Conference on Condensed Matter Physics and Applications**, Manipal University, Karnataka, INDIA, May 23-24, 2016.
4. Oral Presentation: *Synthesis, Structure, and Properties of Multi-Transition “Metal-Substituted Wheel-Shaped Tungstophosphates”*, **International Conference on Multifunctional Materials for Future Applications**, IIT BHU, Varanasi, Oct 27-29, 2015.
5. Oral Presentation: “*Synthesis and Magnetism of Multi-Transition Metal Containing Polyoxometalates*” in the **DFG conference on Magnetism of the transition metal complexes**, May 2005.
6. Poster Presentation: “*Synthesis and Structural Characterization of Transition Metal Substituted Polyoxoanions and Investigation of Their Unique Magnetic Properties*” in the **DFG conference on Magnetism of the transition metal complexes**, January 2006.
7. Poster and Oral presentation: “*Synthesis and Structure of Multi- Transition Metal-Substituted Wheel Shaped Polyoxotungstates*” in the **9<sup>th</sup> Northern-German Doctoral Student Colloquium of Inorganic Chemistry**, October 2006.
8. Poster Presentation: “*Recent Developments on Magnetic Polyanions*” in the **DFG conference on Magnetism of the transition metal complexes**, June 2007.
9. Poster Presentation: “*16-Iron Ring Grafted Inside the 48-Tungsten-8-Phosphate Template Wheel*” in **10<sup>th</sup> Northern-German Doctoral Colloquium of Inorganic Chemistry**, September 2007.
10. Poster and Oral presentation: “*Nucleation Process in the Cavity of a 48-Tungstophosphate Wheel resulting in a 16-Metal-Center Iron Oxide*” in ‘**2<sup>nd</sup> EuChemS Chemistry Congress**’ in Torino, Italy, September 16-20, 2008.
11. Oral presentation: “*Transition Metal Catalyzed Dehydrogenation of Sec-Butylamine Borane*” in ‘**93<sup>rd</sup> Canadian Chemistry Conference and Exhibition (CSC)**’ in Toronto, Canada. 29<sup>th</sup> May - 2<sup>nd</sup> June 2010.



12. Poster presentation: “*New Base Metal Heterogeneous Catalysis for Sodium Borohydride Hydrolysis*” in ‘**H2CAN Workshop**’ at Concordia University, Montreal, Quebec. August 19-20, 2010.

## **Patents**

1. New polyoxometalate useful as catalyst for homogeneous or heterogeneous oxidation of organic substrates and as precursor for preparing mixed metal oxide catalysts.  
**(Ulrich Kortz, Sib Sankar Mal)**, WO2008118619-A1, US2008233033-A1
2. New polyoxometalates as catalysts for the homogeneous or heterogeneous oxidation of organic substrates or as precursors for preparing mixed metal oxide catalysts particularly Mitsubishi-type catalysts.  
**(Ulrich Kortz, Sib Sankar Mal)**, WO2008089065-A1, US2008177118-A1