टाटा मूलभूत अनुसंधान संस्थान
TATA INSTITUTE OF FUNDAMENTAL RESEARCH
(भारत सरकार के परमाणु ऊर्जा विभाग की स्वायत्त संस्था व समविश्वविद्यालय)
(An Autonomous Institution of the Department of Atomic Energy, Government of India, and a Deemed University)
होमी भाभा मार्ग, कुलाबा, मुंबई / Homi Bhabha Road, Colaba, Mumbai - 400 005, भारत / INDIA
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Ref. No. TIFR/NSF/ 24962

This is to certify that:

1. Institute welcomes participation of **Prof. Shriganesh Prabhu as the Co-Investigator** for the project titled '**Novel high performance hydrogen fuel cells with UV modified high proton conductivity nafion membrane**' to be submitted by **Prof. Jayarama A as Principal Investigator** and **Prof. Richard Pinto as Co-PI** both from **Alva's Institute of Engineering and Technology**, Moodbidri and that in the unforeseen event of discontinuance by the Principal Investigator, the Co-Investigator will assume the responsibility of the fruitful completion of the project with the approval of SERB.

2. The Co-Investigator, **Dr. Shriganesh Prabhu** is a permanent employee of this Institute and has **7 years** of regular service left before superannuation.

3. The project starts from the date on which the Institute receives the grant from SCIENCE & ENGINEERING RESEARCH BOARD (SERB), New Delhi.

4. The Co-investigator will be governed by the rules and regulations of Institute and will be under administrative control of the Institute for the duration of the project.

5. The grant-in-aid by the SCIENCE & ENGINEERING RESEARCH BOARD (SERB), New Delhi will be used to meet the expenditure on the project and for the period for which the project has been sanctioned as mentioned in the sanction order.

6. The Institute will provide basic infrastructure and other required facilities to the investigators for undertaking the research project.

Kalobaran Maiti

(KALOBARAN MAITI)

Date: February 22, 2021

Place: TIFR-Colaba, Mumbai

KMA-mlp

H. O. D.
Dept. Of Physics
Alva's Institute of Engg. & Technology
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tifr
Deemed University

Tata Institute of Fundamental Research
टाटा मूलभूत अनुसंधान संस्थान
Homi Bhabha Road, Mumbai 400005, INDIA.

Letter of Acceptance

To:

Alva's Education Foundation (AEF)
Moodbidri, Karnataka-572525

Subject: Acceptance of membership of Research Advisory Board of R & D centers of Institutions of Alva's Education Foundation.

Dear Sir,

Thank you for nominating me as a member of Research Advisory Board of R & D centers of Institutions of Alva's Education Foundation.

I hereby accept to be a member of Research Advisory Board

Best Regards

Prof. S. S. Prabhu,

Department of Condensed Matter Physics

and Material Science,

Tata Institute of Fundamental Research,

Homi Bhabha Road, Colaba,

Mumbai 400005 INDIA

Certificate from the Co-Investigator

Project Title: **Novel high performance hydrogen fuel cells with UV modified high proton conductivity nafion membrane**

It is certified that

1. The same project proposal has not been submitted elsewhere for financial support.

2. We undertake that spare time on equipment procured in the project will be made available to other users.

3. We agree to submit a certificate from Institutional Biosafety Committee, if the project involves the utilization of genetically engineered organisms. We also declare that while conducting experiments, the Biosafety Guidelines of Department of Biotechnology, Department of Health Research, GOI would be followed in toto.

4. We agree to submit ethical clearance certificate from the concerned ethical committee, if the project involves field trails/experiments/exchange of specimens, human & animal materials etc.

5. The research work proposed in the scheme/project does not in any way duplicate the work already done or being carried out elsewhere on the subject.

6. We agree to abide by the terms and conditions of SERB grant.

Name and signature of Co-Investigator: Dr. Shriganesh Prabhu

Date:24-02-2021

Place: TIFR, Mumbai

Novel high performance hydrogen fuel cells with UV modified high proton conductivity nafion membrane

Reference No. : 182021002850

Saved By : Dr. Jayarama A

Saved Date : 25-Feb-2021

PROPOSAL DETAILS

Dr. Jayarama A

jrmarasalike@gmail.com

Associate Professor (Physics)

Alva's Institute of Engineering and Technology

Solapur - mangalore highway, shobhavana campus mijar, moodbidri, Mangalore, Karnataka-574225

Technical Details :

Scheme :	Core Research Grant		
Research Area :	Organic Chemistry (Chemical Sciences)		
Duration :	36 Months	**Contact No :**	+919611945201
Date of Birth :	21-Jan-1976		
Nationality :	INDIAN	**Total Cost (INR) :**	26,40,000

Is PI from National Laboratory/Research Institution ? Yes

Project Summary :

Among the most important sources of renewable and clean energy, the photovoltaic (PV) generation and proton exchange membrane (PEM) fuel cell with hydrogen as fuel, stand apart. While PV with crystalline silicon has made tremendous progress and has been used extensively world over, PEM based hydrogen fuel cells (HFCs) are currently being explored for large scale use. Among the various challenges that are facing PEM fuel cells today are the cost and efficiency; storage of hydrogen is another major problem. The manufacture of Membrane Electrode Assemblies (MEAs) for commercial HFCs requires a simple but cost-effective technology which ensures that MEAs produced with low platinum load are reproducible, durable and low cost. Another way to reduce the cost of hydrogen fuel cells is by pore size tuning and thereby enhancing proton conductivity with UV irradiation of nafion membrane. We have contributed earlier in the development of high performance direct methanol fuel cells (DMFCs) with flow channels having cross-strip design in silicon wafer and by introduction of hydrophobic surface with P(VDF-TrFE) coating on nafion membrane (Patent Appl no: 201841040380), and 2) proton conductivity enhancement of DMFC with exposure to optimum UV radiation (Patent Appl no: 201941009746). Experiments carried out on HFCs with 19mm x 16mm active area with optimally UV exposed nafion have shown a power output enhancement by a factor of 2 for 50um nafion membrane compared to those HFCs with unexposed nafion (Patent Appl no: 201941035383). Hence, this proposal aims for the development of efficient HFCs by introduction of improvements in the existing HFC technology with following techniques: 1) flow channels implemented in a dual-serpentine mode for the flow of hydrogen and oxygen, 2) proton conductivity enhancement with optimal UV exposure of nafion membrane and thereby significantly enhance power output, and 3) Use of uniform dispersion low density platinum deposited on CNTs with carbon paper using RF sputtering technique, Hence, the deliverable of this project is a prototype high efficiency hydrogen fuel cell with dual cell stack size 60 x 40 x 10mm3 and 20W power per cell. Although considerable work is going on in the advanced countries for developing low cost hydrogen fuel cells, R & D work in this area in India is minimal. Hence, use of optimally UV irradiated Nafion membrane and gas diffusion electrodes with uniformly dispersed low density platinum is expected to reduce the cost by a factor of 2 to 3. Hence, we believe this effort will contribute significantly to HFC technology in India. Hence, we request that DST-SERB would approve and fund this very important project proposal

Objectives :

â¢ Design of a prototype Hydrogen fuel cell (HFC) with dual serpentine flow channels with optimum flow channel width to rib width ratio for enhanced HFC performance â¢ Preparation of dual serpentine hydrogen flow channels implemented with CNC machine and coated with Cr/Au layer â¢ Preparation of high performance gas diffusion electrodes (GDE) having aligned CNT matrix with uniform dispersion low density Pt catalyst realized by sputtering process â¢ Improvement of PEM performance with pore-size tuning of nafion by optimized UV irradiation for enhanced proton conductivity and HFC performance â¢ Characterization of UV irradiated nafion using AFM, FESEM, FTIR, FT-Raman and four probe conductivity measurements â¢ Development and optimization of hydrogen humidification setup for controlled humidification of hydrogen fuel for maximum power output â¢ Integration of HFC from anode to cathode: hydrogen flow channels in anode plate, high performance Pt catalyst loaded GDE (anode), UV modified high proton conductivity PEM, uniform dispersion low density Pt catalyst loaded GDE (cathode) with oxygen flow channels in cathode plate â¢ Electrical characterization of HFCs for performance optimization and quantification

Keywords :

PEM fuel cell, Hydrogen fuel cell, flow channels, Proton exchange membrane, Nafion, Gas diffusion electrode

Expected Output and Outcome of the proposal :

The main issues in the use of hydrogen fuel cells are: a) cost and b) efficiency; 1) the cost of fuel cell can be significantly reduced with the use of uniformly dispersed low density platinum deposited using

Other Technical Details

I. Origin of the Proposal:

A hydrogen fuel cell (HFC) is an electrochemical device that converts the chemical energy of hydrogen fuel and oxygen as oxidizing agent into electricity through a pair of redox reactions. Since HFCs are essential for clean energy and energy security of the future, it is very important that India has to invest substantial funds in the area of technology development of HFCs, which will go a long way in building India's energy security. In India, there have been some announcements in the use of HFCs in transportation, for which commercially available high cost HFCs were used. But, to the best of our knowledge, there is very little R & D effort in the development of HFCs in India, partly because of the complexity of the device and partly due to the safety issues with hydrogen gas. Hence, this is the right time both for the government funding agencies and private enterprises to initiate R & D work on HFCs in India.

The main issues in the use of hydrogen fuel cells are: 1) efficiency, 2) lifetime, and 3) cost of production. The efficiency of HFCs primarily depends upon catalytic conversion efficiency and membrane conductivity. It is estimated that the hydrogen conversion efficiency is projected to be 50-60% which is much higher than that of current IC engines which is 20-25%. The key issues of HFCs can be greatly resolved by implementing 1) multi-serpentine flow channels in HFCs which can effectively increase the transport efficiency of reactants and the efficiency of liquid water removal, thereby improving cell performance [1], 2) Cost reduction can be attained by reducing total platinum loading from 0.4 to 0.25 mg $Pt.cm^{-2}$ to low density uniform dispersion loading below 0.1 $mgPt.cm^{-2}$ without compromising efficiency of the fuel cell [2-5], Further, aside from numerous useful applications of HFCs, it still has to go a long way in terms of catalyst for effective commercialization, such as cost, performance, and stability of the process. Pt / Pt-based materials have a strong position in acting as an effective catalyst for HFCs, exhibiting superior catalytic efficiency, electrochemical stability, high current exchange density and excellent functionality [6-9]. However, Pt is costly and has restricted supply for industries because of the scarcity of Pt in earth's crust. As far as HFC applications are concerned, current resources of Pt are not sufficient to meet the requirements [7]. For these reasons, researchers are now primarily focused on the synthesis of ultra-fine Pt nanoparticles, and ultra-low Pt loading on