Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Synthesis & Characterization of Parylene D films on Nafion-117 for Robotic Arm

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Abstract

The era of industrialization needs the discovery of new materials rapidly. The ionic nature of Nafion 117 makes it feasible for the biosensors and other robotic devices. The uncoated nafion 117 is highly unstable at high temperature and evaporative water loss is also present. The coating of noble material make it more efficient and highly stable at adverse conditions. The high cost of noble material may be barrier fpr its day to day applications. Therefore, parylene D has been selected as coating material for base substrate material to maintain its efficiency as well as working. The present study is done to compare the parylene D coated material with the uncoated nafion 117. The water holding capacity and ion exchange capacity has been investigated in the given research.

Introduction

In this decade of invention of new materials composite materials which shows response to the external stimuli in real or near real time is named as smart materials. These materials will show the response in the terms of change of one of its physical property [1]. The advancement of mankind along with technological development develops a need for discovery of new materials. The era of smart materials have been started with the discovery of these materials. Composites materials that react to stimuli by sensing external environment or conditions are come under the same. The change physical properties are shape, viscosity, stiffness and damping. Self-adaptability, self-sensing, memory, and the various functions of the material and structure are all examples of smart materials. These properties made them abled to be used in aerospace, manufacturing, biomedical, space and automotive industries. Smart materials have built in or intrinsic sensors, actuators along with the control mechanism. The smart material has the property of returning to the original state after the removal of external stimuli [2]. These materials have the property of change in their chemical, mechanical and electrical properties due to the desired input [3].

In general, smart materials can be categorized as active and passive. Those materials whose geometry and properties will be changed under the application of external stimuli [4]. Materials which do not responds to the external stimuli are termed as passive smart materials. Active smart materials can be also used for sensing applications and well fitted in the role of actuators. Materials like fibre optics comes under the category of passive smart materials. These materials can be categorized as shape memory alloys, electrostricrive elements, chromogenic materials and piezoelectric material[5].

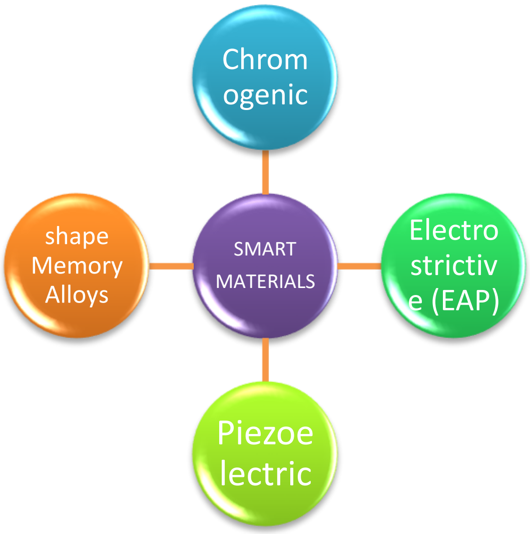

Fig. 1Classification of Smart Materials [6].

Table 1Classification of smart materials [7]

S.NO	**Property changing**			**Energy changing**		
	Material	**Input**	**Change**	**Material**	**Change**	**Effect**
1.	Shape memory	Thermal energy	Change in Crystal phase.	Photoluminescent	Radiation energy in UV medium	Radiation energy in spectrum change
2.	Thermochromic	Thermal energy	Spectral reflectivity	Photovoltaic	Radiation energy	Electric current.
3.	Thermotropic	Thermal energy	Phase change	Electroactive Polymers	Electric current.	Strain
4.	Magnetorheological	Magnetic field	Viscosity	Thermoelectric	Electric current.	Strain

Electronic EAP's

The electronic EAP's are actuated by the high voltage $>150\mu m^{-1}$ which increases the chances of material breakdown due to such high voltage, they also provide better displacement control over the applied DC voltage. They have high energy density and responds in milliseconds on the application of external stimuli [7]. On the contrary the ionic EAP's are activated by relatively low voltage and produce more rapid responses in all direction. These properties of Ionic EAP's make them potential user of robotic application and biometric devices [8]. The comparative property of ionic and electronic EAP's is shown below:

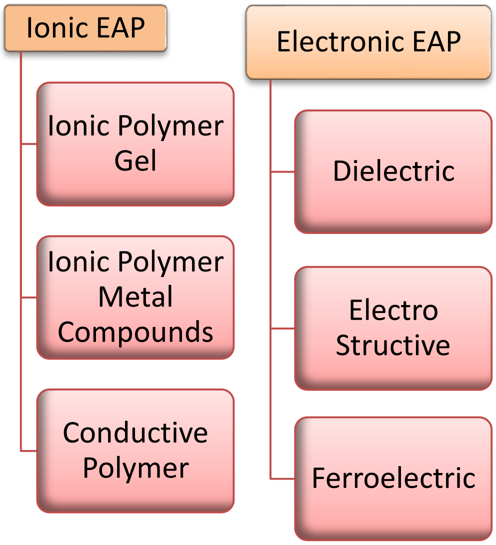

Fig.2. Classification EAP's [9]

Materials and Methods

Materials

Nafion -117 is used as base material which is thin, transparent and plastic membrane showing compatibility with the bio composites; therefore it can be used as biosensors like electronic nose and tongue. In this study nafion-117 is purchased from the Doupoint Kanpur. The parylene dimer which is the member of para xylene group whose backbone consists of para-benzenediyl rings [10]. The parylene dimer required for coating is purchased from the SCH coating solutions Pvt. Limited Hyderabad, India.

Specimen Preparation

The nafion 117 purchased from Doupoint Kanpur is 0.183mm thick and transparent in color. The sample preparation was done in the lab, the five rectangular size strips of dimensions (5*1) cm was cut each weight 0.176gm measured on digital weight balance. The Nafion 117 strip was placed on an aluminum foil for measurement purpose. The pre treatment of nafion 117 was done on magnetic stirrer hot plate than immersed in ionized water & H_2O_2 at 80 degree C for an hour to remove the organic impurities. Further, the nafion 117 strip is immersed in H_2SO_4 at 80°C for approx. 2 hours to protonate.

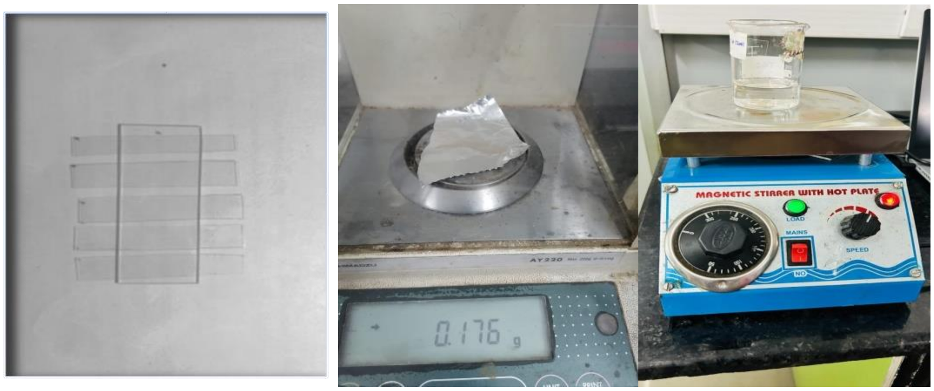

Fig.3. Nafion 117 strips, digital weight balance & magnetic stirrer.

In order to improve the current flow in the nafion 117 the protonation is done making it more suitable to be used as fuel cells, batteries and artificial muscles. This proton conductivity of nafion 117membrane is combined step of catalytic and stoichiometric processes.

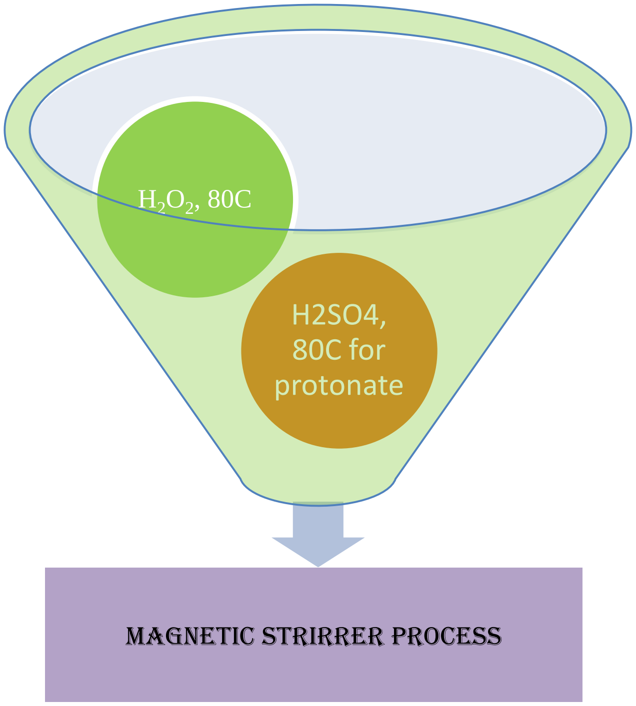

Fig 4. Magnetic Stirrer process of nafion 117 membrane [11].

Deposition of Parylene D on Nafion 117 by CVD

The parylene D dimer is used in raw form and deposited on the Nafion 117 by the Chemical Vapor Deposition method by the use of paryelen coater[12]. This coater uses the specialized coating process to get the specimen coated at room temperature. The parylene dimer is vaporized at approx. 150°C, the dimer breaks into monomer at approx. 650°C and gets deposited on the nafion 117 at 22°C-25°C in vacuum condition. The 800 liters parylene deposition system of SCH coating solutions PVT ltd. has been used for the same[13].

It is appealing that the substrates are kept at room temperature during deposition, enabling parylene to be coated onto a variety of heat-sensitive substrates without thermal damage, The monomer adsorbs to the substrate surface and spontaneously polymerises at room temperature to form linear, high molecular weight parylene films. The Gorham process enables control of the deposition parameters and full conversion of the precursor into parylene[14].

The advantages of CVD is it can be done on multiple substances like glass, ceramics and polymeric materials and uniform extremely thin coatings can be done by this process up to 0.5micro mm in multi direction [15]. These deposited coatings were wear and corrosion resistance with an average life span of 30 years. The plasma technique can also be used for increasing the parylene adhesion to the nafion 117 surface [16].

Fig.5 Coating of parylene on nafion 117 on 800 liters parylene deposition system of SCH coating solutions PVT ltd [17].

Characterization of Parylene D coated Nafion 117

Scanning Emission Microscope (SEM)

For the investigation of surface morphology and cross section of IPMC beam a uniform nafion 117 membrane, images were taken under Scanning Emission microscope. The SEM shows the cross sectional structure of 5x1 cm rectangular film which was exposed to the high focused electron beam for the surface molecular structure study and analysis. The chemical composition of nafion 117 membrane has also been confirmed by this technique.

Fourier-transform infrared (FTIR) analysis

This analysis has been done for chemical composition and functional group analysis.

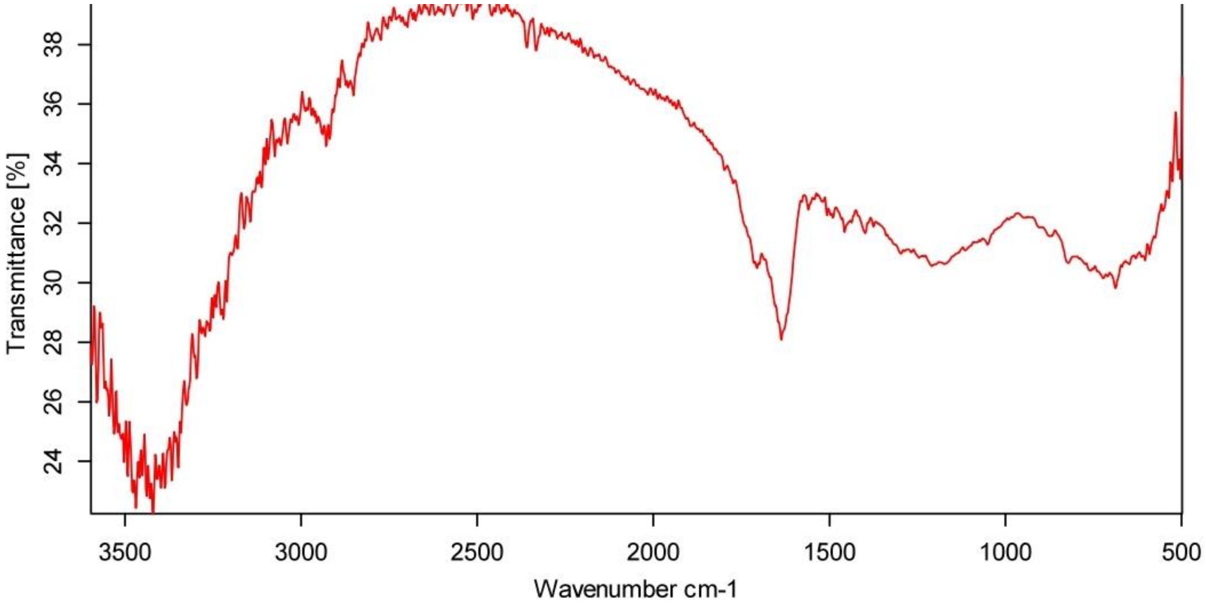

Fig 6. FTIR spectrum.

Ion Exchange Capacity and Water Holding Capacity

This shows the amount of ions a membrane can hold responsible for the optimized performance of IPMC membrane [18]. This can be done by acid base titration. The following steps have been followed to determine the ion holding capacity:

1. Nafion –117 membrane coated with parylene C is immersed in 0.1 N NaOH for 24 hours.
2. 10 ml solution is extracted from the solution and the phenolphthalein is added as titration indicator.
3. 0.1 N HCL is added to neutralize the solution.

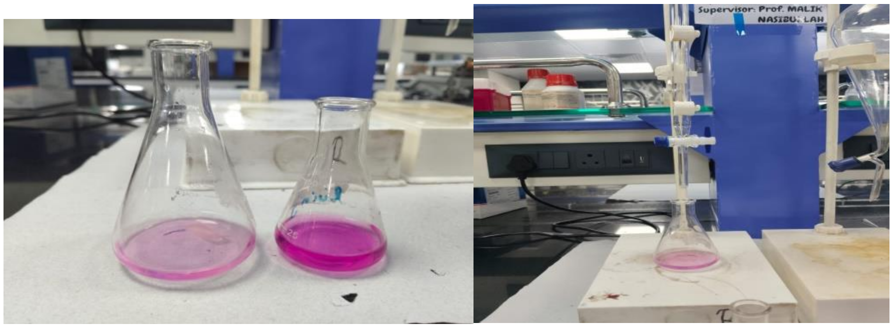

Fig 7. Titration of Nafion 117 membrane in HCL

Water Holding Capacity

The flow of current in the IPMC is due to the movement free water ions. The water from the ionic polymer can be evaporated or lost to the environment for the humidity or any other reason [19]. The high water holding capacity of nafion 117 shows the better actution characteristic of ionic polymer. In order to determine the water holding capacity a pre weighted membrane is immersed into distilled water at room temperature and higher temperature approx. 45°C. The weight of membrane is measured at an time interval of approx. 2 hours to check the performance of ionic polymer[20].

Fig .8. water holding capacity

Result and Discussion

The ionic polymer metal composites are unconventional polymeric composite materials which are highly stable at elevated temperatures. The noble material like platinum, gold, silver and palladium are of higher cost and due to make them unsuitable to be used as day to day application [21]. The parylene D has been substituted for these coating materials which not only lowers the cost of ionic polymer but also give same desirable properties[22].

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