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Synthesis of a Proton Exchange Membrane from Natural Latex Modified with Vanadium Pentoxide for Application in a Fuel Cell

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Abstract : Proton Exchange membranes were synthetized using natural latex of rubber trees from Cartagena, Bolívar. Natural latex was modified by the addition of an inorganic load (V_2O_5) at different amounts (2, 4 and 6%), to improve the proton exchange and physicochemical properties. It was evaluated the ionic Exchange capacity, the water uptake and the oxidative stability for each sample. Membranes loaded with 6% V_2O_5 showed highest water uptake (values 20,34%), and highest mechanical properties. However, ionic exchange capacity of membrane loaded with 4% showed highest values, due to a saturation in membranes. These characteristics attribute high potential for applications in a fuel cell.
Keywords : Fuel cell, membrane, Natural latex, load, vanadium pentoxide.

1. Introduction

Technological advances have grown exponentially over time, proportionally to the demand of the human consumerism, due to that nowadays any transaction or activity require to implement the technology, so it's known that there is technology, is necessary use energy, which has generated to the massive exploitation of the petroleum and other fossils oils, generating the possible extinction of the same, but the demand of energy continues day to day. It is necessary to implement alternative energies to not stop technological growth[1-3]. That's why is doing many researches about alternative energies, which not only are durable but also be friendly to the environment.

Fuel cells are part of this possible solution; these devices transform the chemical energy to electrical energy, using the hydrogen as fuel, generating water from this reaction[4]. There are many types of fuel cell such as the PEM type, (proton exchange membrane), these types of fuel cells generate higher amount of current than others[5].

Actually, Nafion membranes are the most used due to high proton conductivity and a high mechanical stability; however, this type of membrane has high cost[5], and this reason have motivated the developed of many synthetize of polymeric membranes using different polymer to be used in fuel cells[3-11].In this research, natural latex is used as alternative to develop polymeric membranes, it was loaded with vanadium pentoxide and characterized by different methods to define its use in fuel cells.

2. Method and Materials

2.1. Materials

The materials used are: natural latex from de tree *brasilis* ,manufactured by Ladecol, Vanadium oxide, methylene chloride, toluene, ethyl alcohol, hydrogen peroxide, hydrochloric acid, sulfuric acid, acetic anhydride. Sodium chloride, sodium hydroxide.

2.2. Methodology

Initially, membranes without loaded were prepared by a mixture of 30% w/v of latex and distilled water, and the solution was shaking for half hour, thenit was shed in a petri dish of 25ml and it was hoped the solvent vanished for obtaining the membrane laminated. Loaded membranes were prepared by adding different concentrations of vanadium (2, 4 y 6%) pentoxide to the solution and shaking for an hour.

2.3. Characterization

Water uptake inthe membrane was determined by immersion for 24 hours in a container with distilled water; then excess water was removed with a filter paper, the wet weight of the sample was calculated (W_h). Immediately the membrane was dried at 75 ° C for a time of 2 h to determine the weight of the dried sample (Ws). The percentage of water retention was calculated by the following expression[12].

$$\%\ Water\ Uptake = \left(\frac{W_h - W_s}{W_s}\right) * 100 \qquad (1)$$

Proton exchange membranes were characterized by ion exchange capacity that is defined as the number of millimoles of H^+ per unit mass of the dry membrane. This process is carried out by immersion in a solution of HCl for 24 hours. Then, the membrane is immerse in 50 ml of 1M NaCl for another 24 hours to produce the ion exchange between the protons of the membrane and sodium ions.The solution was titrated with NaOH to the equivalence point[13]. The percentage of water uptake is calculated by the following equation[14]

$$IonExchangeCapacity = \left(\frac{V_{NaOH} * [NaOH]}{m}\right) \qquad (2)$$

where, V_{NaOH} is the volume of NaOH used in the titration, [NaOH] is the concentration of Na+ and m is the mass of dry membrane.

Infrared spectroscopy (FTIR) was carried out by the method of the Fourier transform (FTIR) to determine the interaction of sulfonic groups attached to the membrane through sulfonation using the spectrophotometer Nicolet 6700[14].

3. Results and Discussion

Figure 1 shows four type of loaded membranes were prepared(0, 2, 4 and 6% w/w), each membrane was characterized by water uptake, ion exchange capacity, oxidative stability and mechanical properties.

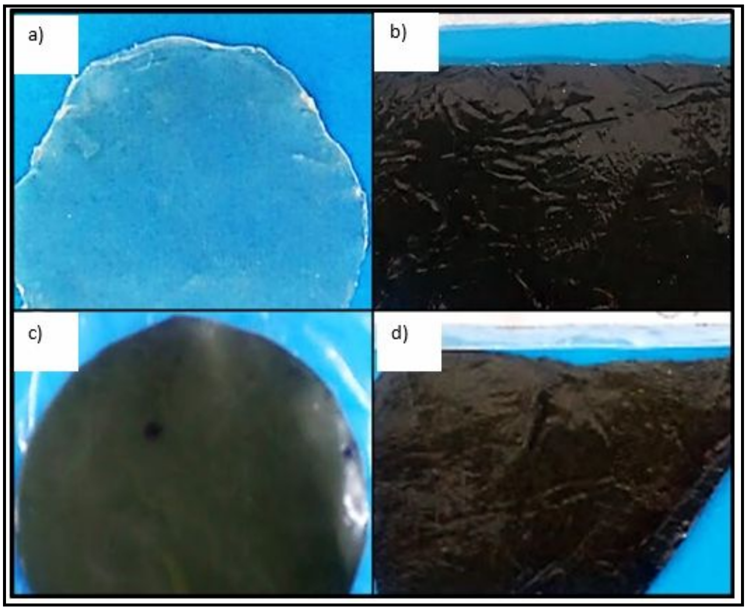

Figure 1. Prepared Membranes: a) Loaded 0%, b) Loaded 2%, C) Loaded 4%, d) Loaded 6%

3.1. Water uptake

Water uptake was determined by the methodology previously mentioned, water uptake is important in the determination of performance of the proton exchange membrane, due to the water is necessary as a mobile phase to facilitate the protonic conductivity; however, the water absorbed also affects the mechanical properties in the membrane[15]

Figure 2 shows that the water uptake increases with increasing the load of vanadium pentoxide. Membrane without load shows a low value of water uptake due to the solids of the polymer, which tend to form films that sealing the pores of the membrane[16]. The addition of inorganic to the membrane increased the water uptake from 11,27% to 20,34 %, due to the oxidative power of the vanadium[17], what produced that the membrane suffered a swelling producing free spaces to the introduction of the water molecules.

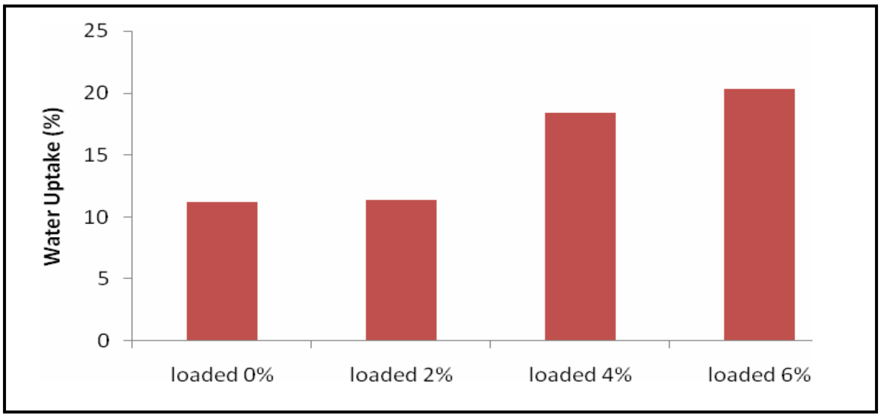

Figure 2. Water uptake of prepared membranes

3.2. Ion Exchange Capacity

Ion exchange capacity is the number of H^+ ions replaceable per unit of mass of the dried membrane, this is one of the characteristic more important in the proton exchange membranes, due to that provides anindication about the acids groups that have H^+ [18]. In Figure 3 is observed that the ion exchange capacity increases in accordance with the addition of the load to the membranes, however it is observed that the membrane loaded with 6% decreases the ionic exchange value.

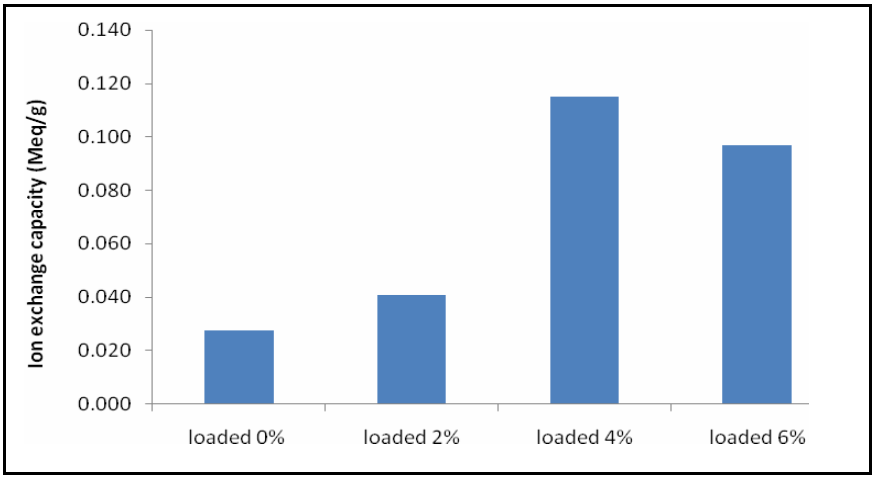

Figure 3. Ion Exchange Capacity of prepared membranes

The high oxidation potential of V_2O_5oxidizes the water molecules present in the membrane, groups of the VOH in the surface of the particles are produced and the water uptake in the membrane is caused, and the increase of available sites to ion exchange[19,20]. However, in the membrane loaded with 6% is observed a reduction in the ionic exchange, what it can be attributed to a lock carried out by the V_2O_5 that interrupts the movement of the ions due to a glut of the same ions[21].

3.3. Oxidative Stability

Samples of each type were submerged in a H_2O_2 solution to determine its stability oxidative, the samples were weighed every 24 hours for 7 days. First day should have a swelling in the membranes, by the absorption of the aqueous part of hydrogen peroxide, however this was controlled due to samples were dried at 80°C in the oven by 1 hour to retire the water excess.

The figure 4 shows that the membrane without load has highest stability. The presence of vanadium in the membrane provides available sites to the oxygen absorption and cause in the membrane an oxidation more effectively for degradation[22].

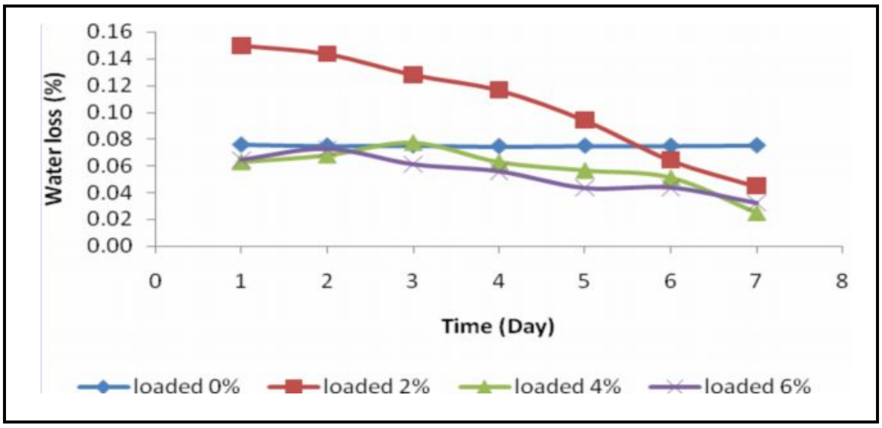

Figure 4. Water loss of prepared membranes in different vanadium pentoxide load

3.4. Fourier Transformed Infrared (FTIR)

This method was used to characterize chemically the synthetized membranes; it was used Nicolet IR equipment to analyze the functional groups. Figure 5 shows the different incidences and spectra for each membrane. Latex or rubber natural is made exclusively of isoprene polymer, in 1600-1670 cm^{-1} (B) range each sample shows peaks corresponding to the tension of C=C bond and the tension out the plane of C=CH bond[23].

In 2700 – 3500 cm^{-1} (A, B) range is shown a width peak corresponding to water used in the solution of natural latex of the synthesis of the membranes. It is known that V_2O_5 showed high absorption in 617 and 827 cm^{-1}(E), associated to vibration V-O-V and O-$(V)_3$, respectively. These signals can be observed in 708 and 822 cm^{-1} (E, F). In addition, it is observed a peak close to 1022 cm^{-1}(D) corresponding to stretch V=O bond[24].

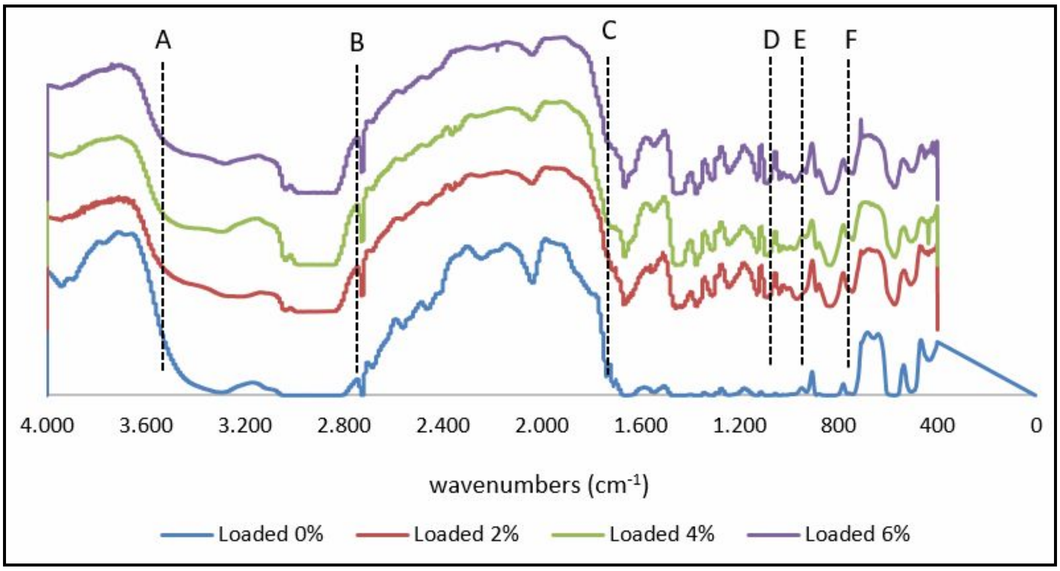

Figure 5. FTIR spectra of prepared membranes

4. Conclusions

In this research was performed the synthesis of polymeric membranes loaded with V_2O_5 using natural latex obtained by the trees from Cartagena. The addition of V_2O_5increases the water uptake and ionic exchange capacity of the membrane, while, the stability of membranes decreases with increasing the V_2O_5 load. The FTIR test shows peaks that indicates the presence of vanadium in the membranes prepared.

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