

onstrate that under these conditions the highest monocell activity and stability was obtained with the electrodes having 40 wt.% PTFE in the catalyst layer. The activity of the cell with electrodes having lower PTFE content decreased with time, while the activity of the cell with electrodes having higher PTFE contents increased with time, but did not reach the level of activity of the cell with electrodes having 40% PTFE in catalyst layer.

The different activities and activity trends in the functioning of the PTFE have been explained by the role played by pores in the catalyst layer during fuel cell operation. The pores have a double function, to supply the catalytic sites with the reagent gas and, to retain the electrolyte for the electrochemical reaction and ionic conduction. Varying the PTFE loading, the ratio of hydrophilic and hydrophobic pores and so the ratio of pores available for electrolyte and gas transport into the catalyst layer changes. The ratio of electrolyte- and gas-filled pores obtained with 40% of PTFE has shown a relatively large electrochemical active volume within the catalyst layer.

This is the consequence of large inter-penetration and sufficient concentration of both liquid electrolyte and reacting gas. When the volume of one of these two phases in the catalyst layer prevails over the other due to different PTFE loading or to the modification of hydrophobic-hydrophilic character of the pores during cell operation, the electrochemical active volume decreases and so does the cell activity.

## P19

### Fabrication of polymer based flexible electrodes for application in fuel cells

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In recent years, research into fuel cells has been given considerable attention because of their attractive features like high conversion efficiency, medium temperature of operation and above all no adverse effect on the environment.

A major area of fuel cell research is on electrode fabrication with inexpensive materials that are light in weight and flexible in nature, fulfilling the requirement of fuel cells for space programmes.

This poster reports the fabrication of polymer based flexible cathodes and their application to the oxygen reduction reaction (ORR) in alkaline medium.

The electrodes were prepared using the polyvinyl chloride (PVC) sheet used as lead-acid battery separators from Exide. These have a thickness of 0.5 mm. A one sq. cm sheet with a connector strip was cleaned with distilled water. For electrodeless deposition of silver film on the polymer sheet, a solution of ammoniacal  $\text{AgNO}_3$ , containing a suitable reducing agent of appropriate concentration, was placed over the sheet

which was bounded with Araldite. The sheet containing the solution was placed over a watch glass and heated to 35°–40°C on a water bath for 10 minutes. A uniform thin film of blackish silver was deposited over the polymer sheet. The electrode so formed was washed thoroughly with distilled water repeatedly and kept in vacuum for drying for 48 hours.

The surface of the electrode was examined under SEM. The electrode was further modified by coating with a very thin film of conducting (poly)phenylene oxide. The conducting polymer coating was made by electro-polymerisation using 50 mM phenol in 3M KOH containing 0.1M potassium ferricyanide. The electro-polymerisation was carried out potentiostatically at 1.6 V versus SCE using a computerised potentiostat/galvanostat (Vibrant model VSMCS 3, Lab., India). The film thickness was controlled by regulating the polymerisation time.

Different electrode-kinetic parameters like apparent exchange current, apparent rate constant and oxygen reduction current at a specific potential for ORR in alkaline medium have been determined from CV studies of these systems at different scan rates.

The results indicate improved electro-catalytic behaviour of modified silver electrodes compared to bare electrodes. Because of extremely lightness of the electrode, effective utilisation of catalytic materials has been found. It seems that increased roughness factor of the electrode arising out of the microporous structure of the polymer net over a spongy silver matrix is probably the reason for enhanced catalytic activity of the electrode.

Possible applications of these electrodes to fuel cells for space programmes are likely.

## P20

### Continuous production of gas diffusion electrodes for fuel cells by a filtration method

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A novel filtration method for preparing PTFE bonded gas-diffusion electrodes for fuel cells was recently proposed by the authors. The method was to make PTFE bonded Raney-Ni anodes for alkaline fuel cells. The method eliminates the problem of structure to a certain extent and has the merits of conventional wet and dry methods. The gas diffusion electrodes can be prepared continuously using this method. A slurry of milled PTFE-metal catalyst is made. The slurry is poured onto an endless moving belt of synthetic felt, continuously fed at a constant and controlled volumetric flow rate through a weir. A vacuum system underneath the felt is used to remove water and thus form a uniform web of PTFE-metal catalyst agglomerates. The web is further dried as it moves.

The charge collector (a metallic mesh) is incorporated into the structure of the electrode by pressing it in with the web of catalyst. The electrode is removed from the felt and further dried by using a drum dryer and hot air. Remaining traces of surfactant can be removed using a spray of solvent. Finally, the electrode material so produced can be cut or rolled as desired. The proposed system is able to control electrode properties such as porosity, catalyst loading and thickness.

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## P21

### Classification and characterisation of primary batteries

#### Part 1: Standardised conditions for the experimental determination of performance characteristics

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Performance characteristics that are addressed in this poster refer essentially to energy content, capacity, discharge voltage, time of discharge, internal resistance and more specifically to standard conditions under which these values are obtained.

The need for relevant standard conditions becomes obvious when studying the technical literature on primary batteries — including technical handbooks and data sheets of manufacturers. It appears that the experimental conditions for product characterisation are differing, thus the performance comparison for a given battery is not always based on the same grounds. In order to permit battery comparison, the IEC (International Electrotechnical Commission) has introduced standardised application and/or service output-tests [1], the results of which are given in terms of discharge durations. An IEC method for the determination of a primary battery's capacity, energy content and load capability is not available yet.

The intent of this poster is to propose a standard method that deals with the above deficiencies — it is based on the so-called standard discharge voltage, which only depends on the electrochemical system and not on the size of the battery, nor on its internal construction. The experimental determination of the standard discharge voltage for a given electrochemical system is obtained via a capacity/discharge resistance curve (C/R-plot) by employing a method to be presented.

It actually is the mean discharge voltage, determined from the discharge curve, that yields 98% of the maximum capacity  $C(\max)$ . The  $C(\max)$  value is characterized by a capacity plateau, i.e.:  $dC/dR = 0$ . The standard method furthermore permits us to address and quantify terms like energy content, capacity and time of discharge. When introducing load resistance  $R(C/2)$ , that yields half the capacity, it is possible to

also address the battery's rate capability under standardized conditions.

When doing so, vague terms like *high rate* or *low rate* in relation to the specific power output  $P^*$  of batteries may be replaced by an experimental value. Values of presently standardized primary batteries were determined to be within a range of  $3 \text{ mW cm}^{-3} \leq p^* \leq 380 \text{ mW cm}^{-3}$ .

To prove the validity of this approach, more than ten different systems (aqueous and non-aqueous) as well as different battery constructions were analysed.

From future work it is expected that the above method may be also employed to characterize secondary batteries.

### Reference

[1] IEC Publication 96, part 2, IEC Central Office, 3 rue de Varamb , CH-1211 Geneva 20, Switzerland.

## P22

### Classification and characterisation of primary batteries

#### Part 2: System and performance characteristics and their application to matters of safety and nomenclature

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#### 1. Application to matters of safety

The approach discussed in Part 1 (Poster 21) of this presentation is helpful in solving existing issues of International Standardisation in the attempt to provide Safety Standards to the public.

One of the issues is the question of electrical interchangeability of batteries having the same physical envelope and identical terminal arrangements, but however, exhibiting markedly different voltages. Reference is made, for example, to 3 V lithium batteries being physically interchangeable with 1.5 V batteries. They never will be standardised by the I.E.C. due to safety reasons.

Two voltage ranges have been defined so far. A formula was derived to describe these ranges. *Voltage range I* encompasses a range from 1.19 V/cell to 1.61 V/cell, *Voltage range II* encompasses a range from 2.3 V/cell to 3.65 V/cell. Within each voltage range, batteries may be manufactured to be physically interchangeable (identical physical envelope and terminal arrangements). For Safety reasons the physical envelope and terminal arrangements of batteries belonging to *range I* must differ from those of *range II* to meet the requirements for standardisation.