

## MICROSTRUCTURE OF PLASTIC BONDED NICKEL ELECTRODES\*

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### Summary

Structure is of great importance in the characteristics of plastic bonded nickel electrodes.

On the basis of SEM tests it has been established that in pressed Ni electrodes some tenth of a millimetre-long PTFE fibres can be found with a diameter smaller than 500 nm. These form a net-like structure in the electrode which holds the active material together without any decrease in the conductivity.

The formation and arrangement of this structure can be influenced by technological parameters.

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### 1. Introduction

Plastic bonded electrodes were first developed for fuel cells. PTFE was frequently used as a bonding material of the air electrode mainly after the research results of Niedrach and his collaborators [1]. Since that time considerable development work has been carried out on the practical use of this plastic material as the bonding material for electrodes of traditional accumulators.

In this respect, the following papers should be mentioned: Mrha *et al.* [2 - 4] and Lexow *et al.* [5].

Results of developments in this field obtained at the Research Institute of the Electrical Industry have already been published by the authors [6, 7], but very little information has been made available regarding the structure of plastic bonded nickel electrodes. From this it follows that the role of the plastic material used in the electrode — in this instance PTFE — in the development and stabilisation of the structure can be described in many ways.

In principle a structure can be imagined where the plastic particles are embedded between the particles of the active material of the electrode and, attached to their surface roughness, they would hold the structure together. This is shown in Fig. 1.

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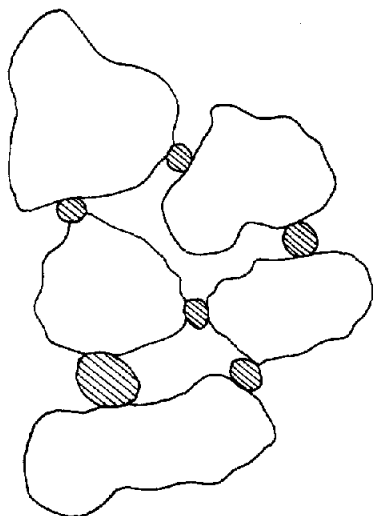


Fig. 1. Outline drawing of one of the possible alternative structures for plastic bonded electrodes.

Support for this type of structure follows from the fact that the plastic bonding material will be used in the form of discrete particles. In the case of PTFE dispersions the dimensions of these particles are 100 - 500 nm.

However, with this structure, electrical resistance would depend to a great extent on the quantity of the bonding material. That is, however, not the case; many authors, *e.g.*, Mrha *et al.* [2], have pointed out that the characteristics of plastic bonded electrodes hardly change over a wide range of bonding material contents, *e.g.*, 3 - 10% of the quantity of the active material. This phenomenon can be explained by a bonding procedure in which the plastic matrix hardly influences the contact of the conducting particles.

In this paper some of the more important results achieved in structure tests of the plastic bonded nickel electrode which has been developed are given. The electrochemical characteristics of the electrodes are dealt with in another paper [8].

## Experimental

The plastic bonded nickel electrodes used in the tests were produced in the Research Institute of the Electrical Industry. The electrodes contained 10% polytetrafluoroethylene (PTFE), 15% graphite, 15% carbon black, and 60%  $\text{Ni}(\text{OH})_2$ .

The electrodes used for the tests had dimensions of  $50 \times 200 \times 3$  mm and were pressed at 120 MPa.

The porosity and the pore size distribution of the electrodes were studied by a Carlo Erba-type mercury porosimeter. On the basis of the results of these tests the pore volume of the electrodes is between 0.25 and  $0.30 \text{ cm}^3/\text{g}$ . On discharge this value decreases by 15 - 20%, depending on the rate of discharge.

In the case of charged electrodes about 50% of the pore volume consists of pores of radius greater than 1000 nm and 20% of the pores have a radius smaller than 60 nm.

The initial charge was at  $0.3 C_b$ ; according to instructions, subsequent discharges and charges were at  $17 \text{ mA/cm}^2$  and  $10 \text{ mA/cm}^2$ , respectively.

In addition to the porosity tests, a JEOL T-20-type scanning electron microscope (SEM) with a resolving power of 20 nm was used. One of the advantages of the use of SEM is its high resolving power which ensures an adequate depth of focus. A surface image of the electrode prior to initial charge is shown in Figs. 2 and 3.

The structure of the porous electrode, and its constituent particles are clearly visible in the picture.

As the surface tests did not give useful information concerning the electrode structure and the bonding method, we next examined the interior of suitably prepared electrode samples.

The characteristic structure of an electrode in the charged state is shown in Fig. 4. It can be seen how well the plastic fibres cover the interior of the electrode with a uniform network.

The structure of a discharged electrode is shown in Fig. 5 and it will be noted that the net structure withstands the volume change on discharge.

An enlarged area of Fig. 5 is reproduced in Fig. 6; this illustrates the "conrescence" possibility of the plastic fibres.

Figure 7 shows plastic fibres loosely situated in the pore of a charged electrode. The sizes of the fibrous structure are easily visible — the diameters are generally between 50 and 500 nm, and their lengths may amount to several hundred micrometers.

The electrode production technology, particularly the pressing conditions, are of great significance in the formation of the fibrous structure. On occasions, some of the plastic particles could only be formed into short fibres. In such a case, the net formation is defective or not uniform (Fig. 8). This problem is under examination.

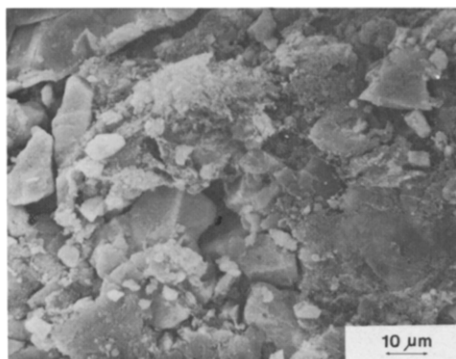


Fig. 2. Surface of an electrode before operation ( $\times 1000$ ).

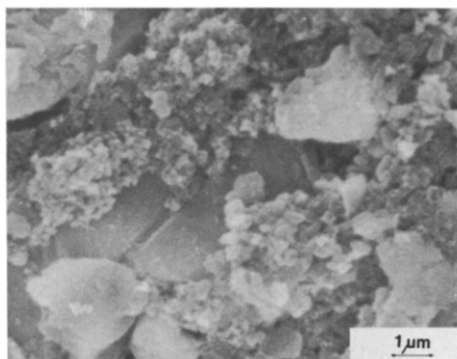
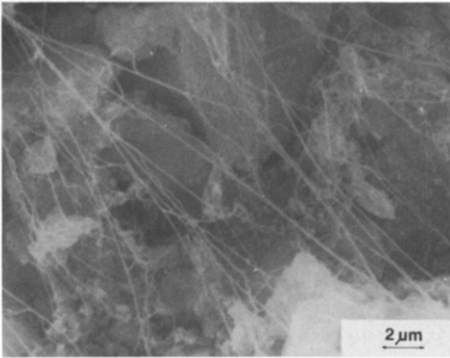
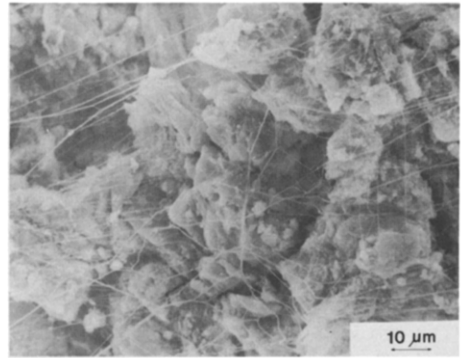


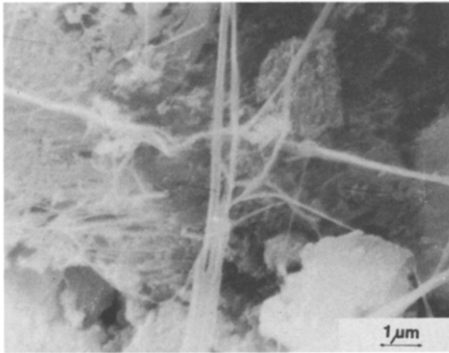
Fig. 3. Surface of an electrode before operation ( $\times 10\,000$ ).



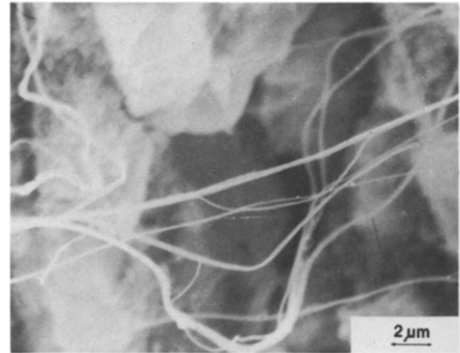
**Fig. 4. Interior of a charged electrode ( $\times 500$ ).**



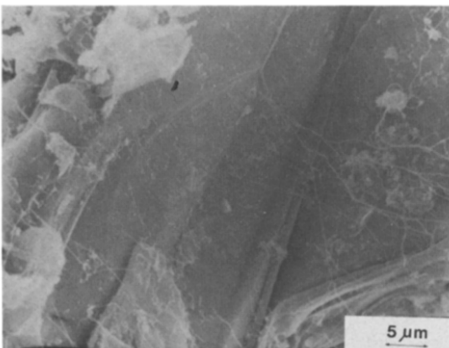
**Fig. 5. Interior of a discharged electrode ( $\times 1000$ ).**



**Fig. 6. Enlarged area of Fig. 5 ( $\times 10\,000$ ).**



**Fig. 7. The plastic fibres to be found in the pore of an electrode ( $\times 5000$ ).**



**Fig. 8. Partly developed plastic structure ( $\times 2000$ ).**

## Conclusions

Our studies unambiguously prove the presence of a bonded PTFE net matrix in the plastic bonded electrode. As the original PTFE dispersion consists of discrete particles, the net structure is formed during the production of the electrode. This structure explains the favourable electrical conductivity of the electrodes and the fact that the conduction is relatively independent of the quantity of the bonding material.

In the net structure the conducting materials are directly in contact with each other and the elastic plastic fibres ensure a favourable microstructure resistant to the volume change caused by the charge-discharge of the electrode.

The diameter of the PTFE fibres is 50 - 500 nm and their length is several hundred micrometers. This structure allows production of low resistance electrodes and thus high loadability.

## References

- 1 L. W. Niedrach and R. Alford, *J. Electrochem. Soc.*, 112 (2) (1965) 117.
- 2 J. Mrha, J. Krejci, Z. Zabransky, V. Koudelka and J. Malik, *J. Power Sources*, 4 (1979) 239.
- 3 V. Koudelka, J. Malik, J. Miskovaly, J. Mrha and I. Krejci, *29th Meeting Int. Soc. Electrochemistry, Budapest, 1978, Extend. Abstr.*, p. 823.
- 4 K. Micka, J. Mrha and B. Klapate, *J. Power Sources*, 5 (1980) 207.
- 5 K. W. Lexow, G. Kramer and V. A. Oliapuram, in J. Thompson (ed.), *Power Sources 8*, Academic Press, London, 1981.
- 6 S. Kulcsár and J. Ágh, *3rd Int. Symp. Electrochemische Stromquellen, Dresden, 1978, Techn. Univ. Dresden Referate*, p. 167.
- 7 J. Ágh, P. Horváth and S. Kulcsár, *Electrotechnika*, 73 (3/4) (1980) 115.