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General Discussion

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General discussion

Have there been significant advances in battery development in the past ten years?

C. A. Vincent (*School of Chemistry, University of St Andrews, UK*). I strongly support the affirmative view. Perhaps the most obvious advance has been in the area of power sources for consumer electronics, where primary lithium systems are now taking over a larger and larger share of the market. Li–MnO_2 AA-size primary (*ca.* 7 cm^3) can deliver 235 Wh kg^{-1} (570 Wh dm^{-3}) in comparison with 86 Wh kg^{-1} (280 Wh dm^{-3}) for the best aqueous systems. Specialized larger primary cells, mainly for military applications, can deliver 300–500 Wh kg^{-1}.

In the past year or so, what may prove an even more significant advance has been made, namely the commercial production of the first reliable rechargeable cells based on lithium, for consumer electronics. With the major increase in demand for portable power by devices such as mobile telephones, 'lap-top' computers, camcorders, etc., this will undoubtedly prove a major market, as discussed in my paper.

Turning to larger battery systems, especially for traction applications, aqueous systems such as lead acid, are now a century old and great improvements have been made over this period, even in very recent times. It must be acknowledged, however, that these technologies are now mature and that further major improvements seem unlikely. So far as high temperature batteries are concerned, these have been under development for 25 years. Whereas the electrochemistry has been fairly well understood for some time, development from the stage of individual cells to practical batteries has been a much slower process and only in recent years has extensive field testing become possible. That such batteries are now serious contenders for a future expanding electric vehicle market was made clear in Sudworth's paper.

The concept of large-scale rechargeable lithium–polymer batteries is even more recent and there is a great deal of basic science in addition to engineering development required before this technology can become proven. Nevertheless, a manufacturing process based on continuous film fabrication and lamination techniques to produce an all-solid-state low temperature power source has much to recommend it. An initial and realistic aim would be for a 20 kWh unit with an overall energy density of 100 Wh kg^{-1}. When this has been achieved, development over what might be one or two decades could see further major improvements.

A. Hamnett (*Department of Chemistry, University of Newcastle, UK*). There are interesting developments in the use of small hydrogen-based fuel cells in which a metal hydride source of hydrogen can be coupled to a simple SPE cell to generate continuous low-current low-power in a maintenance-free environment.

It has to be recognized that replacement of the entire infrastructure in gasoline with one in hydrogen or methanol is improbable as a scenario. In fact if methanol fuel cells are to be adopted, they are not likely, in the first instance, to be employed universally but in niche markets such as taxi fleets or buses.

Why are there not electric vehicles in the UK?

J. Twidell. There *are* electric vehicles in the UK, apart from the very large number of electric milk delivery vans, and there are electric vehicle research and development groups and associations. The need is for national and local government to establish the regulations to encourage a market in zero-pollution vehicles, e.g. the recent legislation that allows local authorities to bar polluting vehicles from streets when air quality is poor; Westminster Council allowing free parking for electric vehicles.

We must all play our part in encouraging such legislation and purchasing electric vehicles for our own use.

R. A. Huggins. What will be the energy vector for fuel cells in the future? Carbon fuels or hydrogen?

J. Twidell. The major constraints in the future will be minimal pollutant emissions and the need to leave fossil carbon underground. Climate change is a scientific possibility and it is ecologically incorrect to bring fossil carbon up to be finally emitted as atmospheric CO_2. Therefore, renewable energy will become a primary energy supply, leading to the obvious intermediate fuels of hydrogen, biogas, ethanol and methanol.

R. M. Dell. While endorsing Professor Twidell's environmental sentiments, I must point out their idealism and that they take no account of the technical and engineering obstacles of developing renewable energy sources in a cost-effective manner, nor of the environmental objections to some forms of renewable energy (e.g. wind generators). The displacement of hydrocarbons as the primary source of world energy will be a long and difficult process.

R. A. Huggins. Much can be gained in the improvement of the specific energy of several battery systems by the development of bipolar designs. The fuel cell development community has been working with multicell stacks in order to produce higher voltages. Several applications will require higher voltages than can be obtained from single cells.

R. M. Dell. Bipolar cell design is particularly well suited to solid state batteries which contain no free liquid and are therefore not subject to leaks and short-circuits. The lithium–polymer battery is a prime example and a conceptual design for a bipolar E.V. traction battery has been published.