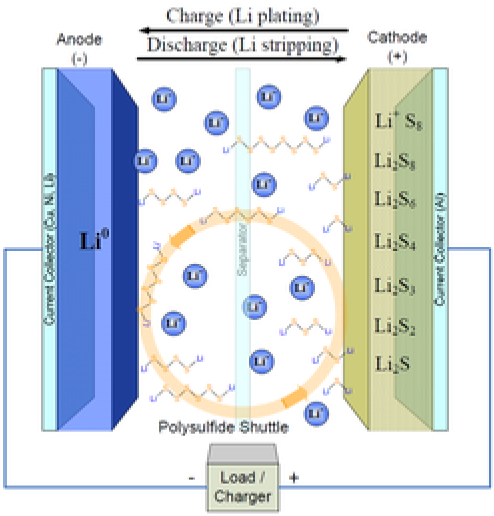
Advances in Battery Technology by **Dr Monica Marinescu** on 20th January 2017

Dr Marinescu said that one of the main factors behind the battery development, that she is engaged in, is a desire to make electric vehicles that outclass those burning fossil fuels – and to reduce the extraction and use of fossil fuels generally.

Batteries do not produce electricity but store it, and can provide effective back up to Solar, Wind and Water generators. They have a range of applications, supported by a range of battery types. For vehicular use they need to be safe, versatile, and able to withstand shock. They can be designed for a high discharge rate – and subsequent recharge rate - with large cross section internal connections. Recharge can be from regenerative braking or a battery charger. Hybrid cars, with back up from an internal combustion engine, can have a low (dis)charge rate battery. Super capacitors can also have a back-up role, as they can rapidly release charge, and be recharged by regenerative braking or more slowly from the battery.

Fuel Cells, together with the means of storing their fuel (usually Hydrogen), are costly and not yet practicable. They have average power and energy densities, so do not give rapid bursts of power.

Lithium is a light element and can be readily oxidised from Li (charged) to Li^+ (the discharge state), making it a good battery anode material. However it is very active chemically and has to be chemically combined to be stable. Batteries need electrically conducting electrodes and an electrically conducting electrolyte; with an insulating separator. The lithium is intercalated in the anode matrix, and as the battery is discharged Lithium ions are transferred to the cathode where it is again intercalated. Early Li-Ion batteries used $LiCoO_2$ for the main cathode material, but $LiMn_2O_4$, Lithium Magnesium Oxide, (with an admixture of $LiCoO_2$) was found to be better. A typical Li-Ion battery, as used in cars such as the Nissan Leaf, is made up of individual cells (in pouches the size of an A5 piece of paper), but housed in a robust casing. Each has a 35 watt-hours (Wh) capacity. A thousand of these will give 30 kWh. A solid electrolyte interface (SEI) between the electrodes and the electrolyte is developed with use, which allows the lithium ions to pass, but otherwise protects the electrodes. It is necessary to balance the cells to prevent any one of them from taking more than its fair share of charging current and running hot - overvoltage protection is provided, and with connections and heatsinks, the cost of the battery is twice the cost of the cells.



The “ions” can be provided by a number of materials including Sulphur and Oxygen. A Li-S battery has a lithium anode and carbon-sulphur cathode. Again the lithium ions transfer to the cathode during discharge. The Li-S battery can be punctured (with a nail !) in safety – it does not explode like a Li-Ion battery. Li-S batteries have low weight and can provide over twice the storage capacity of Li-Ion (a sulphur atom can contribute 16 electrons). They are still under development.

Li-O could provide yet more storage capacity, but are much more difficult to design, and very much for the future.

Battery electrodes are often referred to as plates. A simple voltaic pile such as Volta devised has metal plates of copper and zinc separated by an electrolyte formed of brine soaked cardboard (during discharge the zinc dissolved in the electrolyte and H_2 was given off at the positive, Cu, plate). A Leclanche cell has a carbon rod as the positive ‘plate’– which itself takes no part in the battery chemistry but provides a conducting path for what is effectively an oxygen electrode (from air or MnO_2).

Modern electrodes generally have a porous granular composite structure; they contain reactive agents and conduct electric current to the terminals. However simple the basic electro-chemistry, designing rechargeable batteries has problems: over what temperature range will it work? Material lost from an electrode during discharge and regained on charge causes the electrode volume to change – can this be accommodated within the cell structure, or will it cause the cell to burst? Will the active material distribute itself uniformly in the electrodes during charge and discharge; will it overheat if the charge is too rapid?

Will one large cell work safely or is it better to have a number of small cells; will a number of small cells share the charge or will one try to take the lot? Battery losses increase as current rises – not just ohmic losses in the connections, but due to limits to the rate of ionic diffusion. This particularly affects how fast a battery can be recharged – current limited charging to 80% capacity can be quite rapid, but the final 20% (if you need it) is then trickle charged to avoid damage.

Subtle changes to the physical electrode design or adding chemical modifiers can only be tested by making a cell and trying it. The choice of electrolyte can be critical - how stable is it; what chemical reactions might take place to affect it? Most parameters are not measurable in a closed cell, and the system will work differently if opened. One can only measure the external performance of the cell with its losses.