Supercapacitors are a type of capacitor that has gained appeal as the world has done its best to move away from harmful chemical energy sources to renewable ones. The “super” in supercapacitor comes not from its ability to store energy, but from their ability to deliver power that is unmatched by its counterpart, the Li-Ion battery. The technology that supercapacitors (SC’s) rely on is the electric double-layer (EDL). Helmholtz, Guoy-Chapman, Stern and Graham models are the most highly researched in regard to these EDL’s[[1]](#footnote-1). Instead of conventional dielectrics, these EDL’s rely on a liquid electrolyte dielectric. The electrodes used are also unconventional. Mostly all of electrode research focuses on the use of different types of activated carbon. The specifics of SC’s will be expounded on further in the body of this paper.

Often the most widely varied component of a supercapacitor is its electrodes. The most common types of electrodes are made from carbonaceous materials that are then activated in one of four ways. Carbonaceous materials, like biomass, are used for their especially porous structure. This porous structure leads to a high surface area within the material. The higher the surface area the higher the specific capacitance and power per weight of the electrode[[2]](#footnote-2). These specific power densities can range anywhere from 5-15 kW/kg2. As stated previously, these SC’s have low specific energy densities compared to Li-ion batteries and for that reason SC cells are engineered in combinations of circuit designs. The most commercially and traditionally produced SC have been tested against a variables such as temperature. The variance of the capacitance in a range of common but extreme temperature was only 1-3%2. This is a great feature for the integration of these SC into everyday applications.

Physical (thermal), chemical, physiochemical, and microwave-induced are the four most common processes for creating activated carbon (AC) from base carbonaceous materials. The process of physical activation consists of first heating the carbonaceous substance to a range between 400-850 deg C[[3]](#footnote-3). Once the sample is heated and the surface has blackened, the carbon is activated with oxidizing gases like air, steam, or carbon dioxide that are heated between 600-900 deg C. The major function of this activating gas is to increase the porousness or the overall surface area of the original material.

Chemical activation most commonly utilizes potassium hydroxide and zinc hydroxide to pre-treat the carbonaceous material before activation occurs. Once the precursor material is treated, it is activated by heating to a range of 350-900 deg C3. This heating process is again to make the structure as porous as possible. This process is more environmentally dangerous, time consuming, and expensive claims the author. This is because of the process of washing the AC of the initial activation chemicals. The final porousness has a high variability with chemical ratio and temperature.

Microwave assisted activation was proposed as a way to get around the issues posed by conventional heating. The temperature gradient caused by conventional heating leads to a porously inhomogeneous structure. Microwave heating transfers energy to the carbon by the oscillations of dipole rotations3. This method offers low energy costs and fast activation times. These advantages have caused this method to become a popular method for carbon activation.

An emerging area of electrode research is that of a graphene and graphene-hybrid electrodes. A major drawback to common AC electrodes is their low electrical conductivity. Electrochemically exfoliated graphene (EEG) and EEG/AC hybrids have a much higher electrical conductivity of 2.68E4 S/m as was found in research by Tsaia[[4]](#footnote-4). Other alternatives to AC such as carbon nanotubes also work around this issue, however their structure severely decreases the specific capacitance of SC’s. Graphene seems to work around all of these issues do its high capacitance, porous structure, and high thermal and chemical stability. Pure EEG electrodes when coupled with a potassium hydroxide dielectric reached 65 kW/kg, over a four-fold increase from the best traditional AC electrodes4. The creation of these electrodes is not difficult. Mixing different weight ratios of AC and EEG powder in super-pure water for 24-hours is all that the process consists of. Tsaia first created these EEG and EEG/AC electrodes as small pouches, and then scaled them up to commercial production size. After the scaled versions were put through 10,000 cycles, their capacitance was retained to within 95% the original proving this is a viable option for industry.

Many different components are taken into consideration when attempting to build the most useful supercapacitors. Electrodes, dielectrics, and the circuits in which these SC’s are integrated into are all areas of intense research. These researches are proactively finding the answers that will soon be necessary to the world’s infrastructure.

Notes

* I need to find more information on the double layers at the electrode dielectric interface(Helmholtz-double layer) and have one if not a few paragraphs explaining the physics behind these systems. Encyclopedias and textbooks will probably be my best bet at finding useful information on these. Then include examples from journal articles on how different double layers are being used to make SC.
* I would like to do the same thing with the dielectrics that are used. Without getting into the chemistry too much but just the general physical principles that dictate a need for these electrolytic dielectrics.
* I have read on electrodes pretty extensively, and will add bits of physics into those paragraphs once I have found out more about the double layer and dielectric.

1. https://ac.els-cdn.com/S0169433217336760/1-s2.0-S0169433217336760-main.pdf?\_tid=24e5145a-0b5b-11e8-ba55-00000aacb35e&acdnat=1517934852\_45e8c232543e99de5a0e627eb2408ed1 [↑](#footnote-ref-1)
2. Devillers, Jemei, Pera, Bienaime, Gustin [↑](#footnote-ref-2)
3. Abioye, Nasir Ani [↑](#footnote-ref-3)
4. Tsaia, Caob, Fevrea, Wangc, Todda, Dryfec, Forsytha [↑](#footnote-ref-4)