**Supercapacitors Utilizing ionic liquids Ali Eftekharia,b**

**Summary**

The two main characteristics of a supercapacitor—specific energy density and specific power density—are affected mainly by the electrode and dielectric used in the dielectric.

Different types of electrolytic solutions are used in order to make these dielectrics. Regular ionic solutions (potassium hydroxide, sodium hydroxide etc.) are commonly used in SC, however researchers are branching out to different types of dielectrics. Ionic liquids have been a part of this research. Ionic liquids are chemical salts in the liquid phase. The theoretical motivation for testing IL’s is that the ions in the liquid are better at accumulating at the EDL, meaning they do not diffuse back into the neutral part of the dielectric where the potential changes more slowly. This feature allows for a higher specific energy density in SC, a marked disadvantage of SC’s in general. The cost of these IL’s have abruptly decreased due to an increased supply driven by commercial demand, but still the cost remains an issue for SC developers interested in using IL’s. IL’s are also very susceptible to contamination, and purity is crucial to successful IL implementation. The complexity of the molecules chosen to make the IL’s adds a notable level of difficulty to engineering a SC. A list of different types of SC IL combinations and their respective SED and SPD are given in the table below. The molecules are very complex compared to normal ionic solutions. This complexity pays off however. The graphs in figure 2 compare the SED and SPD of SC’s made with an IL, the commonly used electrolyte KOH, and Lithium hexafluorophosphate electrolyte. All of these dielectrics were coupled to a graphene electrode. The first graph shows the differences in what is called the potential window of a capacitor. The potential window is just the range of potential in which the capacitor can stably operate. From the graph it is seen that the potential window of the IL chosen is over 3x the length of the common KOH dielectric. This is how the energy density of SC is significantly increased by the use of IL dielectrics: the energy stored in capacitors is proportional to the square of the operating potential. IL electrodes are trickier to deal with and more expensive but the payoff is an order of magnitude increase in the energy density. The reason the IL is more stable is because it is made up of individual ions that don’t participate in any reactions over a wider range of potentials. This is also why it is so important that the dielectric be ultra-pure. When coupled to common carbon electrodes, IL’s actually tend to react with the irregularities in the electrode at the boundary. This severely decreases the potential window of the SC. It is reported that some graphene-IL SC’s have reached a potential window of 10V.

Energy density is one of the major drawbacks of SC’s. It is very interesting that graphene electrodes not only significantly increase the SPD of SC’s, but when coupled with IL dielectrics also make astounding progress in increasing the SED of the SC—historically a major drawback of SC compared to Li-ion batteries. The graphene-IL SC seems like the best combination that is being researched right now by far. Right now IL’s are much more expensive than their counterparts. As more research is done and the need for SC increases, hopefully the cost will continue to fall.

**NOTES**

* **There is a lot of great information in the paper used to write this summary. The structure of this summary is somewhat scattered but I wanted to get all of the most important info extracted from the paper and then organize it better in the final draft.**
* **I think I have all the pieces in order to build a pretty strong final draft, I just need to put them in the right order and I’m sure I will realize along the way that I need to add small things.**

1. **Paragraph 1 Introduction**
   1. **History**
   2. **Current Relevance**
      1. **Introduce SED, SPD, Compare to Li-Ion**
   3. **Summary of Components**
      1. **Electrode, Electrolyte, Stern Double Layer**
2. **Paragraph 2 Electric Double Layer (EDL)**
   1. **Theory**
      1. **Graph of ion in electrode**
      2. **Stern Layer Figure**
3. **Paragraph 3 Electrodes**
   1. **Explain favorable AC features (porous etc.)**
   2. **Introduce graphene electrode**
   3. **Stats for both AC and Graphene (compare)**
4. **Paragraph 4 Electrolyte Solution**
   1. **Explain common ES used like KOH etc.**
   2. **Introduce IL dielectric**
      1. **Tie in graphene electrode pairing**
   3. **Compare the two.**
5. **Paragraph 5 Conclusion**
   1. **Personal thoughts on the direction of SC??**
   2. **Restate most important facts, focus on the how of SC**

