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Modeling the distribution of ions in a electrolytic capacitor

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The increase of the density of electrical energy stored in energy storage systems is a crucial element in reducing the volume of on-board systems. Capacitors are made up of two conductive armatures, called electrodes, separated by a dielectric allowing opposing electric charges to be stored on each electrode. This increase can be visualized through an increase in the surface area of the electrodes (engraved, porous [1] or based on nanotubes interdigitated principle [2]).

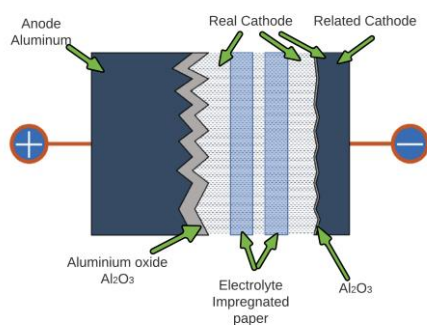


Figure 1. Aluminum electrolytic capacitor.

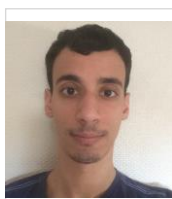
This work aims to develop better generation of energy storage system using concepts based on aluminum electrolytic capacitors (AEC) principle (Figure 1 [3]). The modeling will allow us to understand the physics involved in an energy storage mechanism: an electrolytic capacitor. One of the current highlights of my research is to study the density distribution of ionic species in the electrolyte in an electric field. This understanding will allow us to achieve an optimization of macroscopic parameters such as the capacitance, the Equivalent Series Resistance (ESR) or the temporal response of the system which can be deduce from microscopic analysis. To introduce my modeling, AEC consist of two aluminum electrodes (anode and related cathode), an oxide layer acting as a dielectric and an electrolyte usually boric acid or benzoic dissolved in ethylene glycol or glycerin and water [3]. These chemical mixtures allow the electrolyte to be a very good conductor, over a wide temperature range, in order to bring the negative potential of the cathode (real cathode) closer to the dielectric via ionic transport in the electrolyte. The sheets of electrolyte impregnated paper serve as physical separators limiting the risk of short circuits between the two electrodes. The thin

layer of Al_2O_3 (alumina) is caused by natural oxidation of aluminum which limits corrosion.

My current research consists of studying the distribution of ion concentration, potential and electrical field in the electrolyte for different models at steady state first and then in transient regime. Indeed, the positively or negatively charged ions will be attracted by the electric potential of the electrodes. In addition, they will in turn influence the electric field. This is the coupling between the spatial charge density with the electric potential and this is why the equations for describing the interaction between the ions and the electric field is nonlinear [4]. My modeling is based on microscopic systems with simplified geometries in order to facilitate the resolution of this type of non linear equation. The first model will be a theoretical 2D model with face-to-face plane electrodes in order to compare my model with analytical solutions and check the consistency of the simulation results. The second case will be to study the impact of an etching similar to that of an anode of an AEC (Figure 1). And finally, we will consider a particular geometry allowing, like the etching, an increase in the surface of the electrode. Therefore, we can compare the results and highlight the advantages / disadvantages of each structure. The analysis of the transient regime in these three models makes it possible to study the behavior of the ions subjected to the strong electric field during the charge of the AEC. The temporal evolution of the relaxation resulting from the diffusion of the ions during the discharge of the electrolytic capacitor can also be simulated in order to characterize the electrolytic capacitors operating.

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Jami Torke obtained his B.S in Physics Department from Bourgogne University, Dijon France, in 2018. He received his Master's degree from University Claude Bernard Lyon 1, France in 2020. He is currently a PhD student in Electrical Engineering Department in University Claude Bernard Lyon 1. His thesis is on the modeling, design and experimental characterization of a new energy storage system using Carbon NanoTubes.

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