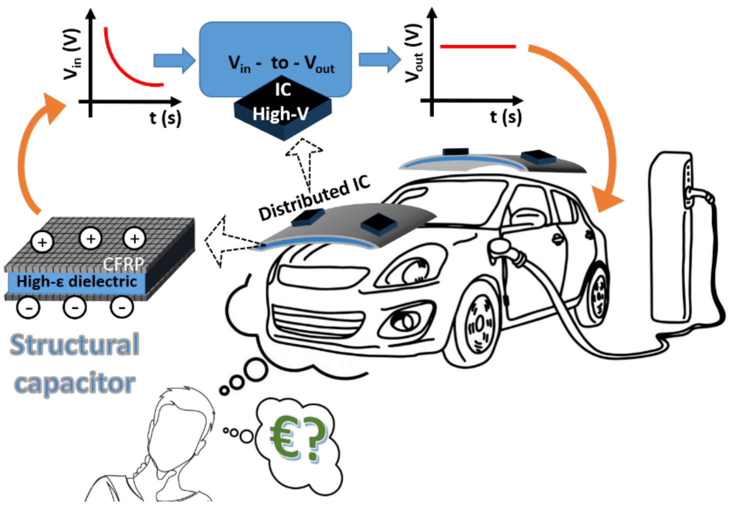
Next generation energy storage in electric vehicles using structural nanocomposite capacitors and integrated circuits

Abstract: Europe aims at leading the world in its transition to a green economy. For this, renewable energy needs to replace non-renewable fossil fuels. The automotive sector is one of the most important examples of a sector where this transition is in full process. A key component in this transition will be the smart storage and management of sustainably produced electrical energy. The current focus of policymakers and the research community lies in the tremendous progress achieved in battery development. However, electric vehicles may also benefit from complementary energy storage devices such as large structural capacitors, which can offer structural functionalities on top of being cost-efficient.

Li-ion batteries are indispensable for the electrification of vehicles due to their high energy density. However, they possess a modest power density. This results in a slow charge-discharge cycle (0.3-5 h). They also have limited cyclability/lifetime (1,000 cycles), are heavy, flammable, and require rare and expensive chemical elements. It would be preferable to harvest energy while driving instead of increasing the battery size to increase autonomy. However, batteries are incompatible with typical energy harvesting situations, such as regenerative braking, that require small but frequent and fast charging/discharging cycles. Likewise, due to their low power density, batteries are not suitable to provide power boosts. On the contrary, (super)capacitors can fill this gap and complement batteries to improve the power boost and driving range of electric cars. A battery pack's efficiency in storing the braking energy is merely 4.5 %, whereas a (super)capacitor can reach up to 50 %. (Super)capacitors have fast charge-discharge cycles (1-30 s) and quasi-unlimited cyclability (1,000,000 cycles). Furthermore, they are light, compact, and do not utilize rare elements or flammable materials.

Based on this background, this project aims to develop structural composite capacitors (SCCs) for electrical energy storage in electric vehicles. SCCs are innovative because they store energy and have enough mechanical integrity to replace some of the vehicle's body parts. Thus, they do not add extra weight to the final system. We will investigate both the technological and economic feasibility aspects of this **"weightless energy"** concept in the context of harvesting energy from regenerative braking in electric cars, buses, or trucks. Compared to supercapacitors containing slow-moving ions and operating at a few volts, we propose exploiting the high voltage capability of electrostatic capacitors to simultaneously increase energy and power density. The main challenges to be solved to turn this promising technology into a success are the limited energy density of capacitors, their variable output voltage, and the cost associated with large area structural devices.



In our interdisciplinary approach, we will develop new carbon fiber-polymer - novel (2D and 3D) nanomaterial - based composite materials to realize high-permittivity dielectric capacitors that can operate at high voltages (100 – 1000 V per cell) and thus provide a high energy and power density while simultaneously offering the mechanical functionality required for structural parts. The materials and processes must be cost-efficient and readily scalable to minimize the economic risk. In parallel, we will investigate and design novel highly integrated DC/DC converters in an integrated gallium nitride (GaN) technology to allow high-voltage operation and facilitate high energy and power densities. These DC/DC converters will be the interface between the widely varying voltage of the SCCs and the required high voltage of the drivetrain in an electric car. The goal is to maximize efficiency, both for charging and discharging, while allowing the capacitors' deep discharge to maximize our solution's energy density. The integration of structural capacitators will thus provide a competitive edge over existing combustion engines, hybrids, or pure battery-electric vehicles.

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Industrial partners:

to be confirmed