Smart Charging of Future Electric Vehicles using Roadway Infrastructure

Developing smart and innovative charging techniques by using renewable energy sources available on roadways (e.g., mechanical pressure and frictional heat)

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Inspired by the fact that there is an immense amount of renewable energy sources available on the roadways such as mechanical pressure and frictional heat, this project presents the development and implementation of an innovative charging technique for future electric vehicles (EVs) by fully utilizing the existing roadways and the state-of-the-art nanotechnology. The project introduces a novel wireless charging system that uses LEDs embedded within fiber reinforced polymer (FRP) coated pavement powered by piezoelectric nanomaterials as the energy transmitter source and thin film solar panels placed at the bottom of the EVs as the receiver, which is then poised to deliver the harvested energy to the vehicle's battery.

Background

Roadways represent an important part of transportation infrastructure, serving as a backbone to enable better mobility for people and goods. Because roadways greatly impact the economic growth and development of communities, state-of-the-art research has focused on planning, designing, and constructing roadways to reduce environmental impact, increase sustainability, and improve the efficiency of transportation flow. However, due to increasingly large demands for reduced driver stress, independent mobility for non-drivers, and increased safety and in-vehicle infotainment, further research is called for on the development of novel roadways that can adapt for future vehicles (e.g., electric or self-driving cars). For example, electric vehicles (EVs) are promoted as a key contributor to building a more sustainable mobility system as they are generally much more energy efficient than those powered by fossil fuels. Furthermore, increasing the use of these electric cars will result in a considerably lower emission of carbon dioxide and other air pollutants, including nitrogen oxides and particulate matter (PM), thereby improving air quality and preserving the environment. However, additional electricity is required to charge EV batteries, which can partially offset EV's benefits through additional emissions resulting from increased electricity production. In addition, these future vehicles need to be equipped with a large-capacity battery pack as an energy storage unit to operate for a satisfactory distance. Lithium-ion batteries, which are the most commonly used in today's EVs, have an energy density of only 90-100 Wh/kg, which is very low as compared with that of gasoline (about 12,000 Wh/kg). Therefore, the lithium-ion battery operated EVs can only operate for about a 300 mile range until they need to be recharged. In addition to the low energy density, contemporary battery technologies have shortcomings of long charging time, large size and weight, limited life time, and relatively high cost. To overcome these challenges, alternative charging strategies that utilize renewable energy sources and take advantage of the existing/new transportation infrastructure (roadways) need to be developed.

Project Summary

The objective of this project is to develop smart innovative charging techniques for vehicles of the future (electric and self-driving cars) - by using renewable energy sources available on roadways such as mechanical pressure and frictional heat (see Figure 1). This proposed research project will test the hypothesis that an unmatched portfolio of advanced energy-harvesting and composite materials, combined with the implementation of efficient power conditioning and delivery circuits, can be utilized to deliver innovative, practically viable smart charging solutions.

The team will achieve this overarching goal by adopting the following two transdisciplinary strategies: (1) implement a novel wireless power system where (a) nanomaterials-powered light-emitting diodes (LEDs) as the energy transmitter, are embedded under a transparent polymer modified nanocomposite (TPMN) overlay, which is reinforced with fiber reinforced polymer (FRP) strips, and (b) thin-film photovoltaic (PV) panels as the energy receiver, are placed under each vehicle and (2) develop an energy harvesting technique to further complement a vehicle's battery recharging system by exploiting piezoelectric and thermoelectric properties of nanomaterials embedded in vehicle tires.

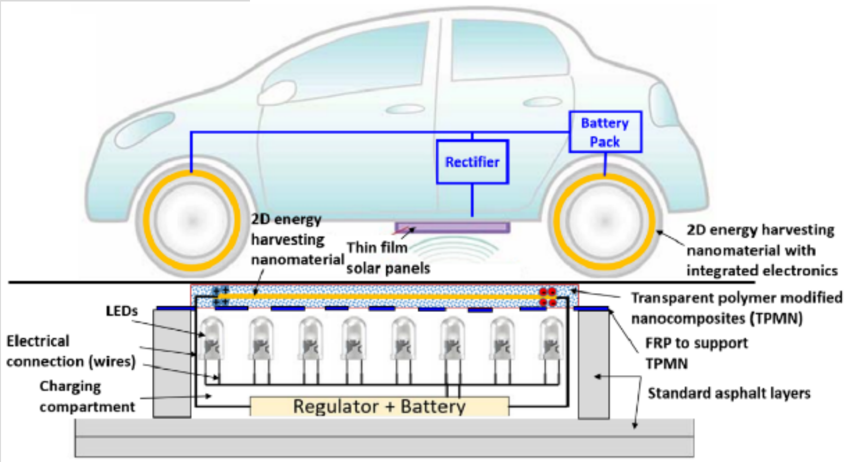

Figure 1. Schematic of the smart charging system proposed for vehicles and roadway infrastructures of the future.

Status Update

The prepared energy-harvestable 2D nanomaterials (EH2N)'s piezoelectricity was experimentally characterized by adopting the piezoresponse force microcopy (PFM) technique.

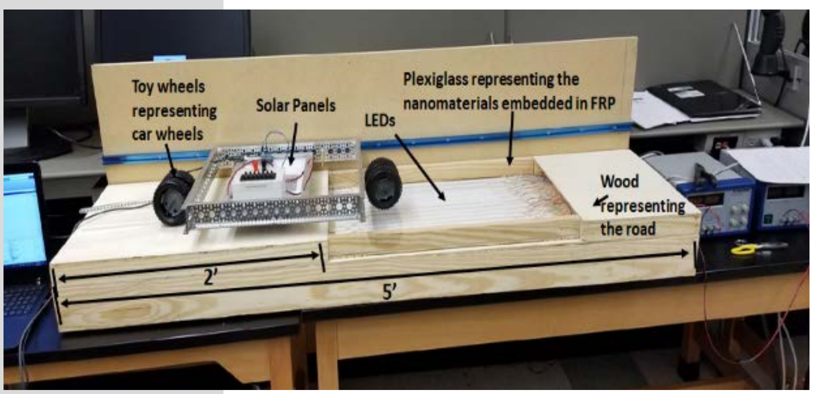

Figure 2. Lab-scale proof-of-concept prototype.

The PFM is a well-established approach for probing piezoelectric properties at the nanoscale, based on the coupling between polarization and mechanical displacement. When the polarization and applied electric field were parallel (top subpanel, +10 V applied), the deformation was positive (i.e., expansion) and the PFM signal was in phase with the probing bias. On the contrary, when the opposite electric field (-10 V) was applied, this caused the EH2N to contract with the consequent lowering of the PFM cantilever tip. Given that all materials that exhibit this so-called inverse piezoelectric effect are essentially piezoelectric, this measurement proves that the prepared nanomaterial is a strong piezoelectric material that can be harnessed for the energy harvesting or mechanical-to-electrical energy conversion purpose.

The research team have developed a lab-scale proof-of-concept prototype of the smart charging system proposed in this work. The prototype consists of a 10' track with five 2' divisions (Figure 2 shows only one division); the divisions alternate from wood to plexiglass, starting and ending with wood. The LEDs are located under the transparent plexiglass which simulates the portion of roadway pavements with EH2Ns embedded. The SiC prototype had 16 strips of LEDs (each strip having 40 LEDs with rating of 21.9 V and 450 mA), and these strips were connected in parallel to have a constant voltage. The LEDs were powered by a DC source in the prototype for the purpose of demonstration.

Impacts

The proposed smart charging system has many potential impacts, including adapting the existing transportation infrastructure for the introduction of electric and self-driving vehicles, reducing the carbon dioxide and the air pollutant emissions from the road transport sector and decrease the dependence on fuel by using permanent, renewable energy sources, thus having a major impact in case of the gas shortage due to extreme weather events (for example, hurricanes). In addition, if compared to other available charging methods, our smart charging system has an advantage over the current solar powered vehicles as it will work under day and night conditions. It also integrates the roadways into the smart system to solve the longstanding issue of renewable energy – intermittent nature of solar or wind energies.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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