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Research Bits: May 9

Optical oscilloscope; all-optical magnetic switching; biodegradable batteries.

MAY 9TH, 2022 - BY: **JESSE ALLEN (HTTPS://SEMIENGINEERING.COM/AUTHOR/JESSE/)**

Optical oscilloscope

Researchers from the University of Central Florida developed an optical oscilloscope (https://www.ucf.edu/news/ucf-develops-the-worlds-first-optical-oscilloscope/) to measure the electric field of light.

The high speed at which light oscillates has made reading its electric field challenging, with current instruments able to resolve an average signal associated with a pulse of light rather than individual peaks and valleys within the pulse.

"Fiber optic communications have taken advantage of light to make things faster, but we are still functionally limited by the speed of the oscilloscope," said Michael Chini, an associate professor of physics at UCF. "Our optical oscilloscope may be able to increase that speed by a factor of about 10,000."

The team found that strong-field nonlinear excitation of photocurrents in a silicon-based image sensor chip was able to provide the sub-cycle optical gate necessary to characterize optical waveforms in the mid-infrared.

"By mapping the temporal delay between an intense excitation and weak perturbing pulse onto a transverse spatial coordinate of the image sensor, we show that the technique allows single-shot measurement of few-cycle waveforms," the researchers wrote.

In demonstrations, the device could perform real-time measurement of the electric fields of individual laser pulses.

All-optical magnetic switching

Researchers from the University of Exeter, Queen's University Belfast, Diamond Light Source, and Lawrence Berkeley National Laboratory found a way to optically switch magnetization (https://www.exeter.ac.uk/news/research/title_889344_en.html), which could enable fast and energy efficient magnetic recording.

The all-optical switching of magnetization allows magnetic bits to be written purely by optical laser pulses without any need for an external magnetic field.

Previously all-optical switching has primarily been investigated in rare earth elements such as gadolinium (Gd) and terbium (Tb). In the new work, the team demonstrated all-optical magnetic switching in nanoscale magnetic storage devices based solely on transition metals such as iron (Fe), cobalt (Co), or nickel (Ni). These can offer lower cost, greater abundance, and higher tunability.

"Our results demonstrate that the key ingredient for helicity independent all-optical switching in rare-earth free synthetic ferrimagnet is to have two distinct transition metal layers," said Maciej Dąbrowski, a postdoctoral research fellow at the University of Exeter. "By employing Ni3Pt and Co layers we were able to create an imbalance of spin-polarized current for one trillionth of a second (10^{-12} s) after the laser excitation, which ultimately leads to the magnetization switching."

The switching can be achieved independently of the light polarization and over a broad temperature range. The researchers believe this could be a step toward more efficient information storage in data centers.

Biodegradable batteries

Scientists from Nanyang Technological University Singapore (NTU Singapore) developed paper-thin biodegradable zinc batteries (https://www.ntu.edu.sg/news/detail/batteries-of-the-future-could-be-paper-thin-and-biodegradable) that could be used for flexible electronics.

In a proof-of-concept, a 4cm x 4cm square of printed paper battery could power a small electric fan for at least 45 minutes. Bending or twisting the battery did not interrupt the power supply.

In another experiment using a 4cm x 4cm battery to power an LED, the scientists showed that despite cutting away parts of the paper battery, the LED remained lit, indicating that cutting does not affect the functionality of the battery.

"Traditional batteries come in a variety of models and sizes, and choosing the right type for your device could be a cumbersome process. Through our study, we showed a simpler, cheaper way of manufacturing batteries, by developing a single large piece of battery that can be cut to desired shapes and sizes without loss of efficiency. These features make our paper batteries ideal for integration in the sorts of flexible electronics that are gradually being developed," said Professor Fan Hongjin from the NTU School of Physical and Mathematical Sciences.

The researchers used a 'sandwich' design for the battery. It is based on cellulose paper reinforced with a hydrogel to fill up the fiber gaps found in the cellulose, forming a separator.

Electrode inks are then screen printed onto both sides of the cellulose paper. The anode ink is mainly made up of zinc and carbon black. For the cathode ink, the scientists developed one type with manganese and another with nickel as a proof-of-concept, though the research team said that other metals could possibly be used.

After the electrodes are printed, the battery is immersed in an electrolyte. A layer of gold thin foil is then coated on the electrodes to increase the conductivity of the battery. The final product is about 0.4mm thick.

Lee Seok Woo, an assistant professor from the NTU School of Electrical and Electronic Engineering, said, "We believe the paper battery we have developed could potentially help with the electronic waste problem, given that our printed paper battery is non-toxic and does not require aluminum or plastic casings to encapsulate the battery components. Avoiding the packaging layers also enables our battery to store a higher amount of energy, and thus power, within a smaller system."

At the end of the battery's life, it can be buried, where the hydrogel and cellulose are naturally broken down by soil microorganisms. To demonstrate the paper battery's biodegradability, the NTU scientists buried it in the soil of a rooftop garden on the NTU campus. The hydrogel-reinforced cellulose paper started fracturing after two weeks, and degraded completely within a month.

"When decomposition happens, the electrode materials are released into the environment. The nickel or manganese used in the cathodes will remain in their oxide or hydroxide forms, which are close to the form of natural minerals. The zinc found in the anode will be naturally oxidized to form a non-toxic hydroxide. This points to the battery's potential as a more sustainable alternative to current batteries," said Fan.

Next, the team plans to demonstrate integration of the printed paper battery to other printed electronics, electronic skins, as well as energy storage systems deployed in the environment. They think that the battery could have applications in foldable electronics or biomedical sensors.

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