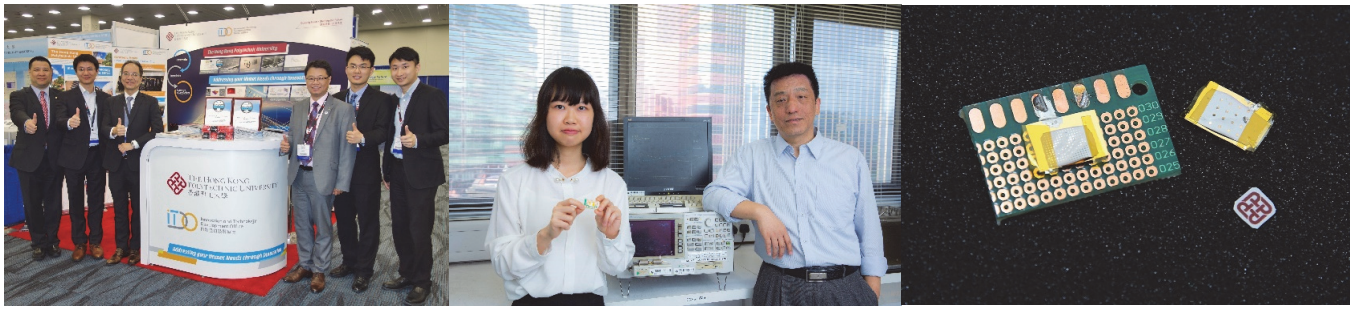
Composite multilayers capacitors with colossal permittivity for electronics and energy storage applications

— Professor HAO Jianhua, Professor & Associate Head, and Ms TSE Mei-yan, Department of Applied Physics, The Hong Kong Polytechnic University

— Contact: Ir Steven LAM, Manager, Innovation and Technology Development Office, The Hong Kong Polytechnic University| Telephone: (852) 3400 2864 | Email: steven.tf.lam@polyu.edu.hk



Brief Description of Technology in layman's terms: With global demand for energy storage growing rapidly over the past decade, surging research efforts worldwide have been put in developing novel capacitors, which can achieve fast charging, high power density and long cycling lifetime than conventional batteries. This innovation of PolyU is the first report on simultaneously achieving large dielectric constant (i.e. a lot of energy can be stored); negligible dielectric loss (i.e. energy not leaking out and being wasted easily) and high energy density in flexible composite capacitors based on metal-ion co-doped colossal permittivity materials.

The host titanium dioxide used in this colossal permittivity system is environment-friendly, non-toxic and abundant. The process developed (solution casting and hot-pressing technique) is relatively simple and low cost for mass production of the composite films, as the ceramic powder fillers are fabricated by conventional solid-state sintering method. The dielectric capacitors we developed based on composite multi-layers present a relatively high dielectric constant with exceptional low loss. The maximum energy density achieved simultaneously is remarkable compared to nano-composites with other ceramic particle fillers. Such novel composite multi-layers capacitors are expected to be greatly superior to the conventional one-dielectric currently used in such systems. Moreover, power electronic applications are currently limited by the capacitor size and performance. Multi-layered capacitors can be easily patterned, with fully solid-state construction, thus being superior to conventional electrochemical construction in many aspects including improved safety.

Technology Development Status: Prototype

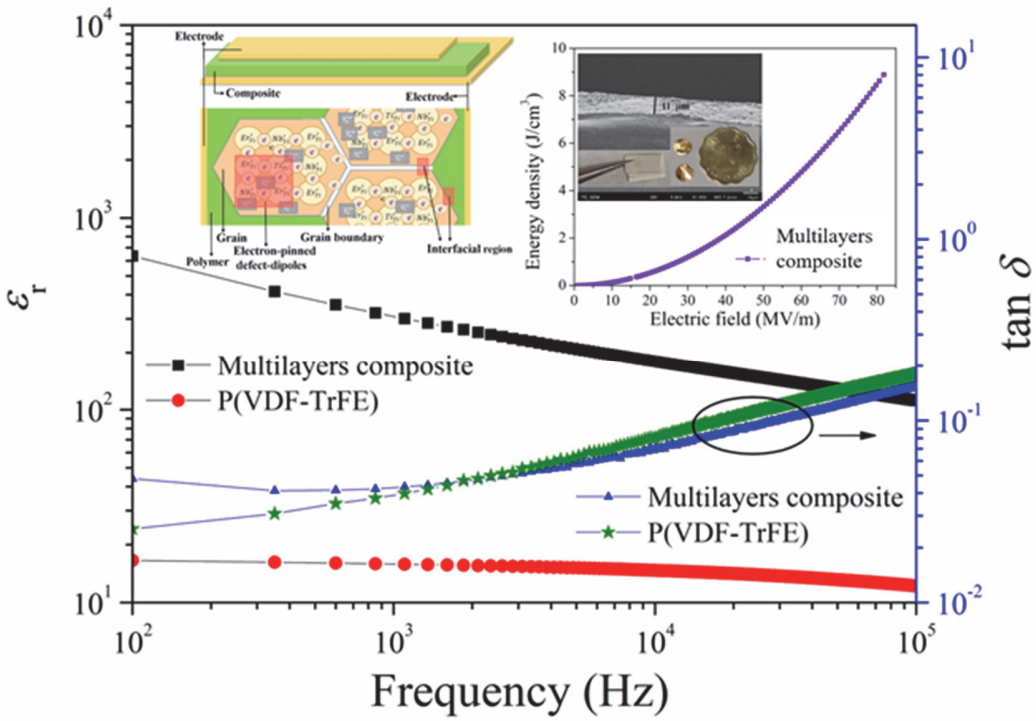
Application Area: Materials, Chemical; Energy, Efficiency, Resilience

Technology Readiness Number: TRL 2

Technology Keywords: colossal permittivity co-doped TiO2, polymer composite dielectrics, permittivity films

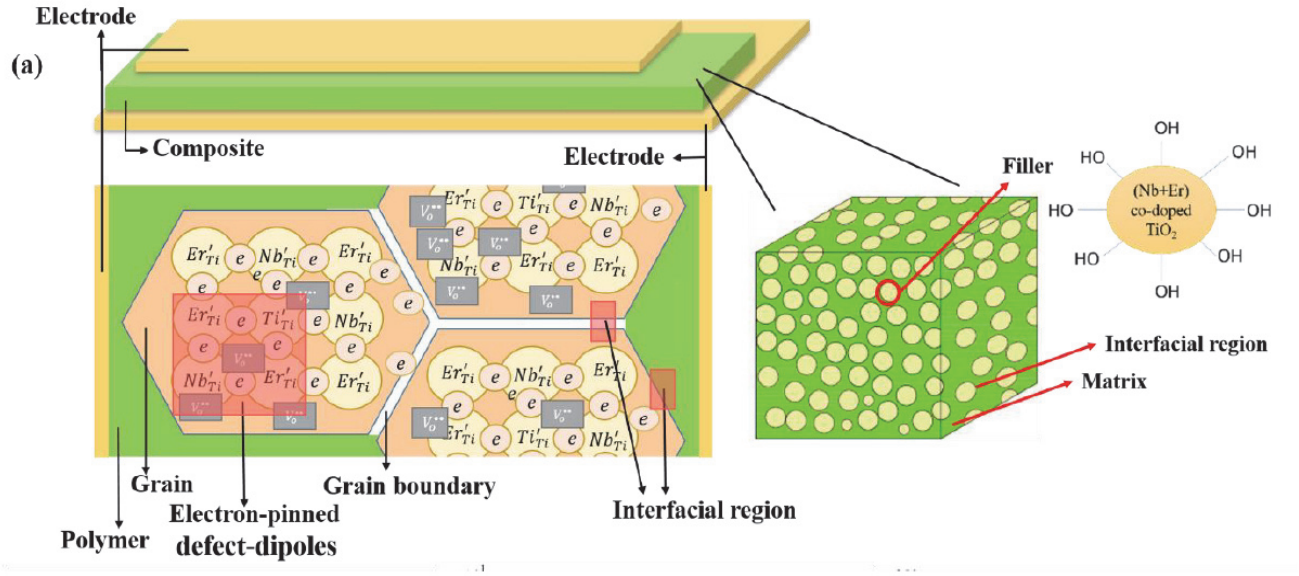
Market Keywords: solid-state capacitors, energy storage, microelectronic

Detailed Technology Summary: Materials with colossal permittivity (CP) have shown great technological potential for advanced microelectronics and high-energy-density storage applications. Several types of CP materials have been studied. Still, it is challengeable to maximize their performance as they show drawbacks in two aspects: temperature/frequency dependent properties and high dielectric loss. In our work, original CP ceramic capacitors exhibited high-performance dielectric behaviors, including temperature and frequency stable CP value (10^4–10^5) and sufficiently low dielectric loss (0.03). These results indicate a high reliability of the capacitors. In addition, technology on ceramics were extended to multi-layer-structured ceramic/polymer composite films. Surface hydroxylated ceramic fillers, embedded in copolymer matrix achieved high dielectric constant up to 300 and exceptional low dielectric loss down to 0.04 over a broad frequency range, as well as a high energy density of 8.9 J/cm^3 at breakdown field of 82 MV/m. Therefore, this composite film capacitors have great technological potential for many applications. In microelectronic systems, thin-film dielectric with high capacitance due to its minimal thickness and being located close to the microprocessor can reduce inductance. Thin-film capacitors can increase the capacitive density and drastically reduce the capacitor area, offering performance, volume, and cost advantages over discrete ceramic capacitors.



Value Proposition: In this work, the host titanium dioxide used in this colossal permittivity system is friendly to the environment, non-toxic and abundant. The process developed, which is solution casting and hot-pressing technique is relatively simple, low cost and mass production for the composite films since the ceramic powders were fabricated by conventional solid-state sintering method. By contrast, the fabrication process for nano-size materials or core-shell nanostructure are usually complicated, and the production capacity might not suitable for mass production-scale. Our developed dielectric capacitors based on the composite multilayers present a relatively high dielectric constant with exceptional low loss. The maximum energy density achieved simultaneously is remarkable compared to those nanocomposites with other ceramic particle fillers. Such novel composite multilayers capacitors are expected to be greatly superior to conventional one dielectrics currently used in systems. Moreover, power electronics applications are currently limited by the capacitor size and performance. Multi-layered capacitors are easily patterned in principle and fully solid-state construction, offering many merits such as improved safety consideration when compared to conventional electrochemical construction.

Market Strategy, Customers & Partners: The global Advanced Energy Storage Systems market grew from USD 1.51 billion in 2012 and is expected to reach approximately USD 3.42 billion by 2022, reported by Crystal Market Research. Novel capacitors batteries are higher capacity with increased capacitance. These batteries generally hold 10 to 100 times more energy per unit volume than the conventional batteries, which is driving the market of alternative capacitors battery market. As global electricity generation has grown rapidly over the last decade, capacitors with high performance are coming in market as a new solution. Currently, North America is leading the market of capacitors batteries, closely followed by Europe region. Asia-Pacific has emerged as fastest growing market. In addition, advanced energy storage systems market is extensively spread over different organizations The key market players are AES Energy Storage, LG Chem, GE and Alevo, which are intensely putting advanced energy storage systems into R&D to create advanced technology.



TechConnect
WORLD INNOVATION
CONFERENCE & EXPO

20th ANNIVERSARY

NANOTECH 2018 CONFERENCE & EXPO | SBIR/STTR SPRING INNOVATION CONFERENCE | DEFENSE TECHCONNECT DTC SPRING CONFERENCE

TechConnect
WORLD INNOVATION
CONFERENCE & EXPO

20th ANNIVERSARY

Innovation Presentation

Composite multilayers capacitors with colossal permittivity for electronics and energy storage applications Title of Technology

Mei-Yan Tse and Jianhua Hao*

Presenter: Victor Zhao or Steven Lam

*Corresponding Author Email: jh.hao@polyu.edu.hk

The Hong Kong Polytechnic University

NANOTECH 2018 CONFERENCE & EXPO | SBIR/STTR SPRING INNOVATION CONFERENCE | DEFENSE TECHCONNECT DTC SPRING CONFERENCE

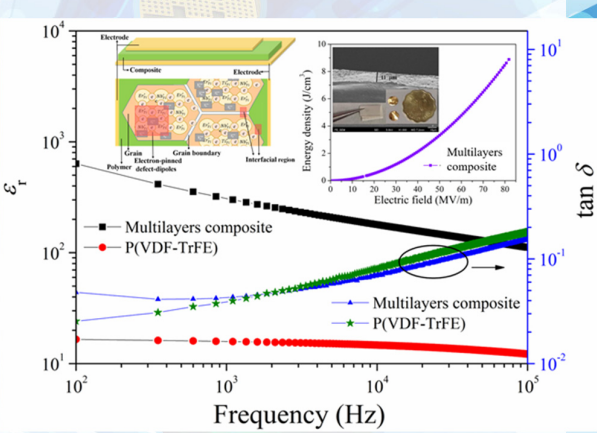
Innovation Description

- Multilayer and flexible capacitors composed of metal-ion doped TiO_2 colossal permittivity material/polymer composites by simple techniques.
- Demonstrate simultaneously

✓ Large dielectric constant meaning a lot of energy can be stored.

✓ Negligible dielectric loss meaning energy doesn't leak out and get wasted easily.

✓ High energy density.



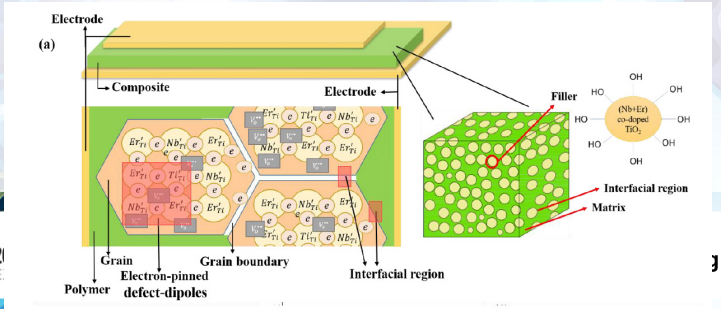
Ceramics	Polymers	Polymer/ceramic composites
• High ε_r • Low tan δ • Brittle • Relatively small breakdown strength • →Low energy density	• Relatively high breakdown field strength • Flexible • Easily operate into large area films • Low ε_r	• Exhibiting the combined advantages of ceramics and polymers • Light weight, scalable and are easily fabricated into complex shapes

TechConnect WORLD INNOVATION CONFERENCE & EXPO techconnect.org

TechConnect

Advantages offered by our technology:

- Host titanium dioxide: friendly to the environment, non-toxic and abundant.
- Solution casting and hot-pressing technique: relatively simple, low cost.
- Mass production available.
- Multi-layered capacitors: easily patterned, improved safety consideration when compared to conventional electrochemical construction.
- Composite and flexible capacitors superior to conventional dielectrics currently used in systems.



TechConnect

Value of the Innovation

- The Hong Kong Polytechnic University 'owns' the technology.
- United States Provisional Patent Application No. 62/663,340

  Title: Multilayer and flexible capacitors with metal-ion doped TiO_2 colossal permittivity material/polymer composites

  Inventors: Jianhua HAO and Mei-Yan TSE
- The work was supported by the grant from Research Grants Council of Hong Kong (GRF No. PolyU 153004/14P).

Market Size/Impact

- The global Advanced Energy Storage Systems market grew from USD 1.51 billion in 2012 and is expected to reach approximately USD 3.42 billion by 2022.
- Currently, North America is leading the market of capacitors batteries, closely followed by Europe region. Asia-Pacific has emerged as fastest growing market.
- The key market players are AES Energy Storage, LG Chem, GE and Alevo, EEStor, which are intensely putting advanced energy storage systems into R&D to create advanced technology.

Source:

Crystal Market Research

WEIR R D，NELSON C W.Electrical-energy-storage unit utilizing ceramic and integrated-circuit technologles for replacement of electrochemical batteries：US, 7595109[P].2009-09-29.

What are You Looking For?

- Status of the technology Development: Prototype
- Further R&D is needed to enhance performance and make practical components if additional funding is provided (~US$ 500K)
- We are seeking licensing partner for our US provisional patent

TechConnect WORLD INNOVATION CONFERENCE & EXPO NANOTECH 2018 CONFERENCE & EXPO SBIR/STTR SPRING INNOVATION CONFERENCE DEFENSE TECHCONNECT DTC SPRING CONFERENCE techconnect.org

TechConnect

Contact Information

- Contact names:

  Victor Zhao or Steven Lam

  Innovation and Technology Office (ITDO)

  The Hong Kong Polytechnic University, Hung Hom, Hong Kong

  T 852 3400 2806; **F** 852 2334 8755; itdo@polyu.edu.hk

  https://www.polyu.edu.hk/itdo/en/index.php

- Reference your showcase booth number & description in show guide. "Composite multilayers capacitors with colossal permittivity for electronics and energy storage applications" Showcase Booth #: 523