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Professor Bong-Joong Kim's joint-research team has developed a capacitor that has a low dielectric rate that can recover the dielectric constant

- GIST (President Kiseon Kim) School of Materials Science and Engineering Professor Bong-Joong Kim and California Institute of Technology Professor Julia R. Greer have led a joint-research team to develop the world's first 3D-nanolattice * capacitor that can maintain and recover dielectric breakdown strength ** and the ultra low-k dielectric *** characteristics during compressive deformation.

* 3D-nanolattice: a 3D-nanolattice structure in which ceramic nanotubes are regularly arranged in a unit cell shape by using sophisticated 3D laser printing and atomic layer deposition resulting in a material with a low dielectric rate and good mechanical strength

** dielectric breakdown strength: a phenomenon in which electrical resistance between electrically insulated materials is reduced, resulting in high current flow; dielectric breakdown strength is how much the insulation properties of a material can be maintained

*** ultra low-k dielectric: A material with a low dielectric constant of less than 1.5 (a dielectric constant, a physical unit that indicates the effect of the medium between the charge on the electric field when the electric field acts between the charges)

- In addition, the mechanisms by which this recovery occurs are identified through real-time imaging, mechanical characterization, theoretical modeling, and current-voltage curve analysis.
- The development of materials with low dielectric constant is gaining attention because it plays a key role in the application of high efficiency microelectronic

devices such as computer processing, wireless communication, and autonomous vehicle. However, if the porosity * is increased to lower the dielectric constant, the mechanical strength and the dielectric breakdown strength are seriously weakened, limiting development.

* porosity: the amount of gaps present in the interior of the solid; the ratio of the volume of the holes to the total volume in the porous material

□ The researchers fabricated a nanolattice capacitor of 99% porosity made of alumina (ceramic) tubes to lower the dielectric constant and to acquire the desired physical properties.

- This capacitor has an ultra-low dielectric constant ($k = 1.06-1.10$), at the same time a Young's modulus * of 30 MPa, a yield strength ** of 1.07 MPa, and has a shape recovery during the compression stress cycle. This structure was used to quantitatively analyze the dielectric breakdown characteristics, dielectric characteristics, and conduction mechanisms while repeatedly applying compressive deformation of up to 50%.

* Young's modulus: a mechanical property that measures the stiffness of a solid material as the relationship between stress and strain in a material in the linear elasticity regime of a uniaxial deformation

** yield strength: the stress at which the material exhibits permanent deformation; the actual approximation of the elastic limit

- Through real-time observation and simulation, the electrical insulation breakdown and dielectric constant did not expand after bucking * the nanotubes constituting the 3D-nanolattice at a stress of about 50%, and the shape of nanolattice, dielectric breakdown, and dielectric constant were simultaneously restored as the stress decreased. This resilience also increases as the number of nanotubes buckled permanently increases as the electrical/mechanical stress repeats. The conduction mechanism at this time also changes from the Schottky emission ** to the Poole-frankel emission *** method.

* bucking: a phenomenon when a compressive load is applied in the direction of the length and the width to a thin and long rod or a flat plate having a width larger than the thickness; a bending or a large deformation may be caused by a load less than a proportional limit of the material

** Schottky emission: a phenomenon when the thermionic emission from the cathode surface of the electron tube increases by the electric field

*** Poole-frankel emission: a phenomenon in which most heat-electron emissions increase within a material, usually with respect to a very large field

- In a thin film structure consisting of alumina in general, destruction occurs as soon as only 17% of porousness is applied. However, three-dimensional-nanoratis capacitors with 99% porosity developed in this study are stable at 200V and have very strong electrical strength.

- Professor Bong-Joong Kim sid, "The results of this research are the first case to elucidate the mechanism of the dielectric/electrical characteristics of ultra-low dielectric materials, which no one has done either at home or abroad. Most of all, by developing capacitors whose dielectric breakdown strength and dielectric constant are restored by themselves, we expect to be able to use them in future for flexible electronic device systems or next-generation systems that can recover lost information from electrical/mechanical shocks in the future."

- This research, which was led by GIST School of Materials Science and Engineering Professor Bong-Joong Kim (co-corresponding author) and California Institute of Technology Professor Julia R. Greer (co-corresponding author) with School of Materials Science and Engineering researcher Min-woo Kim and Caltech researcher Max L. Lifson, was carried out with the support of the GIST-Caltech Research Collaboration grant and was published online in *Nano Letters*, the world's top authority on nanoscience, on July 12, 2019.

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