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Professor Bong-Joong Kim and Professor Myung-Han Yoon's joint research team develops photocombustion process for flexible switching devices

□ GIST (Gwangju Institute of Science and Technology, President Kiseon Kim) School of Materials Science and Engineering Professor Bong-Joong Kim and Professor Myung-Han Yoon's joint research team was the first to develop a deep ultraviolet photocombustion * using a sol-gel ** solution process *** and applied a polycrystalline thin film of vanadium dioxide ****, one of the transition metal oxides *****, to provide a flexible plastic substrate.

* photocombustion: Deep ultraviolet (DUV) photocombustion is a compound word for photoactivation and combustion, which is a process where a combustion reaction material capable of causing an explosive exothermic reaction at a specific temperature and an ultraviolet ray having high energy capable of breaking the internal bond are obtained.

** sol-gel: Particles that are dispersed in a solution is a sol, and a gel is a solid or semi-solid form when heated or cooled and are used in the manufacture of metal oxides, especially silicone and titanium oxides, by producing solid materials crystallized from small molecules in small units.

*** sol-gel solution process: forming a thin film by making various functional metal oxide materials that can be applied on a substrate as semiconductors and insulators

**** vanadium dioxide: an oxide of a blue crystal with a rutile structure and has the properties of an insulator that is not electrically conducting below 68 degrees Celsius and has a metal body that conducts electricity above it

***** transition metal oxide: a compound in which oxygen atoms are bonded to transition metals and is widely used in catalysts and semiconductor materials

- In addition, a real-time transmission electron microscope technique capable of rapid imaging (30 frames per second) at high resolution of atomic size by sending gas into the transmitting electron microscope (TEM) * identified the mechanism by which the thin film of vanadium dioxide changes from an amorphous solid to a crystalline solid.

  * transmission electron microscope: a microscope that can be magnified by hundreds of thousands of times by shooting a high-voltage electron beam into a thin material

□ The 'metal-insulator phase transition' * phenomenon of vanadium dioxide (VO2) occurs very quickly at a rate of tens of femtoseconds (10-15 seconds) at a temperature close to room temperature (68 degrees Celsius), drawing attention as a key material for next-generation switching devices (e.g. thermal sensors, optical sensors, gas sensors, thermal imaging cameras, transistors, and non-volatile memory).

  * metal-insulator phase transition: 'phase transition' refers to a change in the atomic or molecular structure and compositional state of a substance (ex. solid↔liquid↔gas) when it changes from an energized metal state to a non-electric insulator due to temperature changes, etc.

- In the previous studies, physical vapor deposition methods (eg, physical vapor deposition *, sputtering **, etc.) were mainly used to make crystalline vanadium dioxide thin films, which can only be manufactured at high temperatures of 500 degrees Celsius or higher, so it cannot be applied to plastic substrates vulnerable to high temperatures.

  * physical vapor deposition: a process of depositing a material coated on the surface of a workpiece by a physical method in a vacuum, such as metal films, alloy films, as well as vapor deposition compounds, ceramics, semiconductors, polymer films, etc.

  ** sputtering: a type of vacuum deposition method used in the integrated circuit production line process, which is widely used in industry, by accelerating ionized argon plasma, etc. at a relatively low vacuum to hit the target and eject the atom to create a barrier on substrates such as wafers and glass

□ In this study, the researchers succeeded in lowering the critical temperature for forming a crystalline vanadium dioxide thin film on a polyimide substrate from 500 degrees Celsius to 250 degrees Celsius through a deep ultraviolet photocombustion process method based on a sol-gel solution process. This new concept of photocombustion process consists of adding ammonium nitrate *, which can serve as an oxidizing agent for combustion, to the vanadium dioxide precursor

in an appropriate proportion and irradiating deep ultraviolet (DUV). Through this process, radicals ** which effectively induce the removal of organic impurities and the polycondensation *** between metals and oxygen were generated, thereby significantly lowering the crystallization temperature.

> * ammonium nitrate: A nitrate of ammonia having a chemical formula of NH4NO3, a white crystalline solid at atmospheric pressure, room temperature. This is a high-nitrogen fertilizer commonly used in agriculture and is also used as an oxidizer in rocket fuels and explosives (IED). The melting point is 169.6 °C and begins to decompose at about 210 °C.
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> ** radical: a chemical term that indicates the state in which atoms and molecules' internal electrons collide with other electrons or ions or are easily reacted with other substances due to the action of a catalyst
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> *** polycondensation: the process of producing polymers from dual or multi-functional compounds by removing low molecular weight byproducts (e.g. water, alcohol, organic impurities, etc.)

- Furthermore, an array of vanadium dioxide elements in a large area of several square centimeters on flexible plastic substrates was created, bent at a high-angle dozens or more times, and then analyzed the characteristics of electrical resistance changes depending on temperature. It was confirmed that all parts of the device array exhibited uniform and reliable phase transition characteristics.

□ Professor Bong-Joong Kim and Professor Myung-Han Yoon said, "This research result is the first to synthesize vanadium oxide crystal thin film, which is spotlighted as insulator-metallic phase deformation, on plastic substrates using a solution process to secure the reliability of the device, and is expected to be used for large flexible switching and electronic devices."

- In addition, "The deep ultraviolet photocombustion method, which has been applied mainly to amorphous sol-gel metal oxide semiconductors for displays, has opened new opportunities for utilizing a variety of crystalline functional metal oxide thin films beyond metal oxide insulators."

□ This research was led by GIST Professor Bong-Joong Kim (corresponding author) and Professor Myung-Han Yoon (co-corresponding author) and researcher Yong-Ryun Jo (first author) and researcher Won-June Lee (co-first author) with support from the Samsung Research Funding & Incubation Center and was published online on April 9, 2020, in the *Chemistry of Materials* (IF: 10.159). In addition, it was selected as a cover paper in recognition of its importance to academics and the general public.

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