Gwangju Institute of Science and Technology

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Professor Sanghan Lee's research team develops highly durable photoelectrode for water decomposition and hydrogen production using solar energy

☐ GIST (President Kiseon Kim) School of Materials Science and Engineering Professor Sanghan Lee's research team develops highly durable photoelectrode for water decomposition and hydrogen production using solar energy.

- Using a thin film deposition method, this highly durable photoelectrode will contribute to continuous water decomposition and hydrogen production technology by using solar energy.

☐ To produce hydrogen, which is seen as a next-generation energy source, a photoelectric chemical battery system will be used to break down water molecules (H_2O) into hydrogen molecules (H_2) and oxygen molecules (O_2) and produce hydrogen in an eco-friendly manner by using solar energy.

- In the photoelectric chemical battery system, the photoelectrode plays an important role in generating hydrogen (H_2) and oxygen (O_2) molecules. In particular, for efficient and stable water decomposition, it is important that charges in generated through solar energy move smoothly to the interfacial surface of water molecules without recombination * or chemical reaction with other ions.

* recombination: the process by which the generated electrons and ion pairs are combined to dissipate the charge

☐ A representative semiconductor material that is attracting attention as a photocathode for generating hydrogen molecules (H2) is a copper-based metal oxide that is abundant on the earth and can effectively absorb solar energy from a wide range of wavelengths. The photocathode thin film using copper-based metal oxide is mainly used in solution process, which requires post-heat treatment for crystallization of thin film.

- At this time, for photocathode thin film manufactured by the solution process, structural defects that hinder the flow of charge transfer are likely to occur, thereby reducing the durability of the photocathode due to photocorrosion. Therefore, it is essential to use a protective layer coating or an expensive catalyst on the surface of the photocathode to prevent the photocorrosion of the photocathode. To solve this problem, a thin film deposition process for improving the quality of the photoelectrode thin film is required.

☐ The team fabricated a high-density heterostructure * (copper bismuth oxide (CuBi2O4) and nickel oxide (NiO)) photocathode thin films using pulsed vapor deposition **. The photocurrent density of the designed high-density heterostructure photocathode thin film is 1.5 times higher than that of single-layer copper bismuth oxide photocathode photocurrent density. In particular, it was confirmed that the high-density heterostructure photocathode thin film was stably maintained for about 8 hours without increasing the dark current *** (about 80% of the initial photocurrent density ****). This long-term stability is about 3 times longer than the stability test time (2-3 hours) of copper bismuth oxide photocathodes fabricated by the previously reported solution process.

* heterostructure: bonding between different heterogeneous crystals

** Vapor Deposition can be classified into two types according to the deposition process: one is Physical Vapor Deposition (PVD) and the other is Chemical Vapor Deposition (CVD). In general, PVD is a thin film is deposited through a vacuum process, CVD has a difference that a thin film is formed through a high temperature heat treatment process using a chemical solution. Pulsed laser deposition (Pulsed Laser Deposition) is a physical vapor deposition method that can produce a high-quality thin film in a vacuum atmosphere using a high energy laser light source.

*** dark current: current caused by potential difference when sunlight is not irradiated on the photoelectrode

**** photocurrent density: current generated by electron-ion pairs generated at the photoelectrode per unit area when sunlight is irradiated on the photoelectrode

☐ Professor Sanghan Lee said, "The photoelectric chemical battery system requires long-term stability of the photoelectrode for practical hydrogen production through water decomposition, and it is possible through this research to

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manufacture durable photoelectrode by using physical vapor deposition such as pulsed laser deposition, which is expected to improve the stability of photoelectrodes."

☐ The research was led by GIST Professor Sanghan Lee and performed by Ph.D. student Jongmin Lee and master's student Hongji Yoon as co-first authors and was supported by the Creative Materials Discovery Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT. The research was published on September 9, 2019, in *Chemical Communications* (IF = 6.164) and was selected as the cover paper in recognition of its excellence.

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