3D-printed smart contact lens with navigation function

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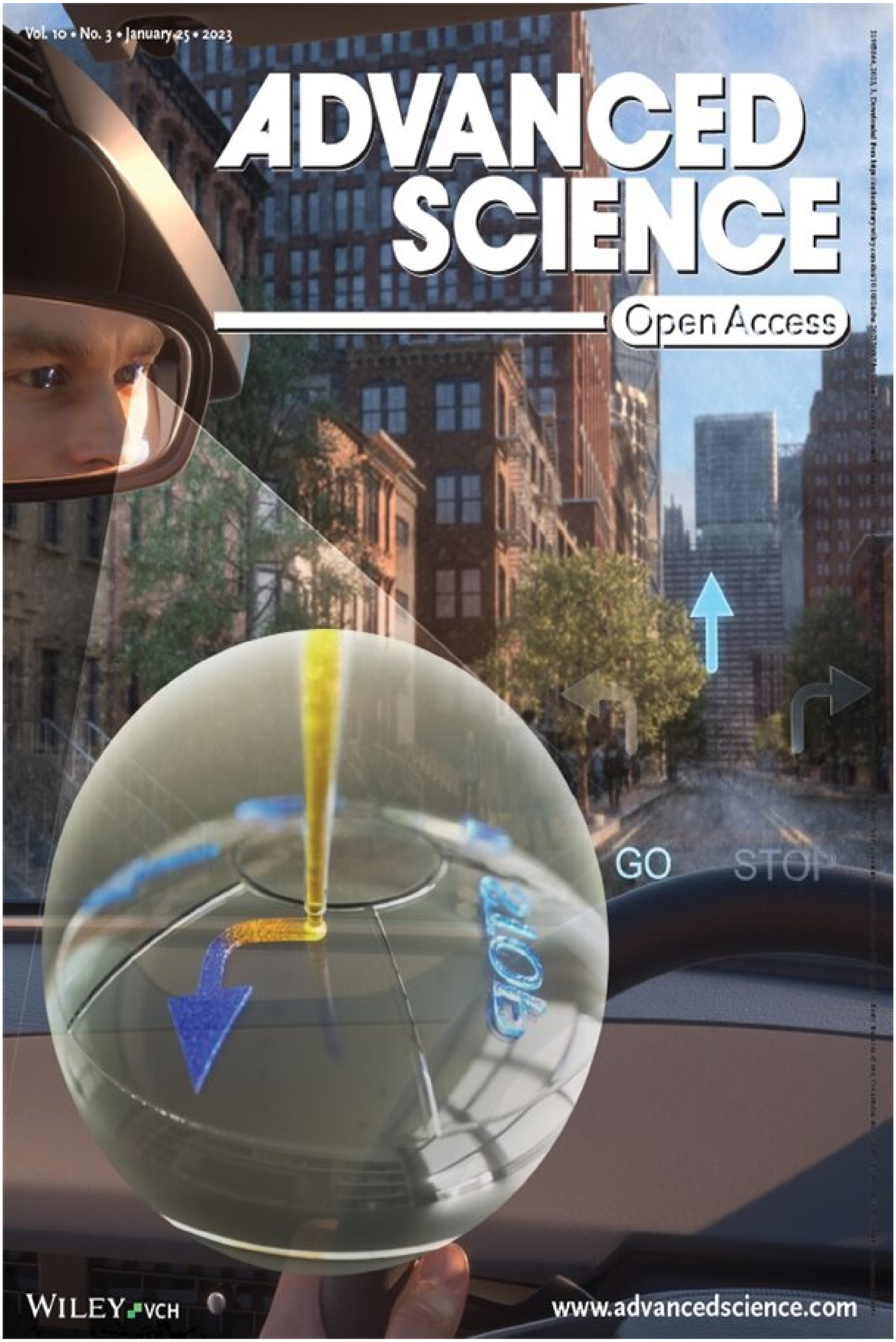
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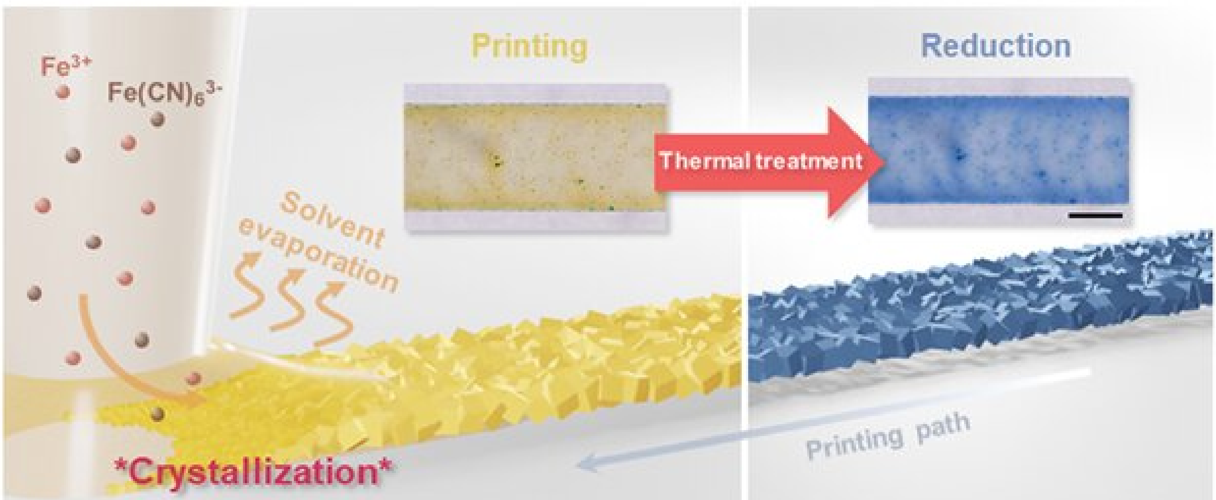
Cover image from *Advanced Science*. Meniscus-guided micro-printing of Prussian Blue is realized by the localized crystallization of $FeFe(CN)_6$ on the substrate confined by the ink meniscus and thermal reduction of the crystallized $FeFe(CN)_6$. This strategy is capable of being used as an electrochromic display to give real-time directions on an augmented reality (AR) smart contact lens device. Credit: Korea Electrotechnology Research Institute

Dr. Seol Seung-Kwon's Smart 3D Printing Research Team at KERI and Professor Lim-Doo Jeong's team at Ulsan National Institute of Science and Technology (UNIST) developed core technology for smart contact lenses that can implement augmented reality (AR)-based navigation, with a 3D printing process.

A smart contact lens is a product attached to the human eye like a normal lens that provides various information. Research on these lenses is currently focused mainly on diagnosing and treating health problems. Recently, Google and others are developing smart contact lenses for displays that can implement AR. Yet many obstacles to commercialization exist due to several technical challenges.

In implementing AR with smart contact lenses, electrochromic displays that can be driven with low power are necessary, and a "pure Prussian blue" color, with cost competitiveness and quick contrast and transition between colors, is attracting attention as the lens' material. In the past, the color was coated on the substrate in the form of a film using the electric plating method, which limited the production of advanced displays that can express various information (letters, numbers, images).

The achievement of the KERI-UNIST team lies in the fact that it is a technology that can realize AR by printing micro-patterns on a lens display using a 3D printer without applying voltage. The key is the meniscus of used ink. This is a phenomenon in which a curved surface is formed on the outer wall without water droplets bursting due to capillary action when water droplets are gently pressed or pulled with a certain pressure.



Crystallization of $FeFe(CN)_6$ occurs on the substrate in a region confined by the meniscus, forming the uniform pattern. $FeFe(CN)_6$ pattern is converted to the PB ($Fe_4[Fe(CN)_6]_3$) via thermal reduction. Credit: Korea Electrotechnology Research Institute

Prussian blue is crystallized through solvent evaporation in the meniscus formed between the micronozzle and the substrate. The meniscus of the acidic-ferric-ferricyanide ink is formed on the substrate when the ink-filled micronozzle and substrate come in contact. Heterogeneous crystallization of $FeFe(CN)_6$ occurs on the substrate within the meniscus via spontaneous reactions of the precursor ions (Fe^{3+} and $Fe(CN)^{3-}$) at room temperature. Simultaneously, solvent evaporation occurs at the meniscus surface.

When water evaporates from the meniscus, the water molecules and precursor ions move toward the meniscus surface by convective flow, generating a preferential accumulation of the precursor ions in the outer part of the meniscus. This phenomenon induces the edge-enhanced crystallization of $FeFe(CN)_6$; this is crucial for controlling the factors that influence the crystallization of $FeFe(CN)_6$ in the printing step to obtain uniformly printed PB patterns on a substrate.

As with conventional electroplating, the substrate formerly had to be a conductor when voltage was applied, but a great advantage of using the meniscus phenomenon is that there is no restriction on what substrate can be used because crystallization occurs by natural evaporation of the solvent.

Through the precise movement of the nozzle, the crystallization of Prussian blue is continuously performed, thereby forming micro-patterns. Patterns can be formed on both flat surfaces and curved surfaces. The research team's micro-pattern technology is very fine (7.2 micrometers), and it can be applied to smart contact lens displays for AR, as the color is continuous and uniform.

The main expected application area is navigation. Simply by wearing a lens, navigation unfolds in front of a person's eyes through AR. Games such as the popular "Pokemon Go" can also be enjoyed with smart contact lenses, not smartphones.

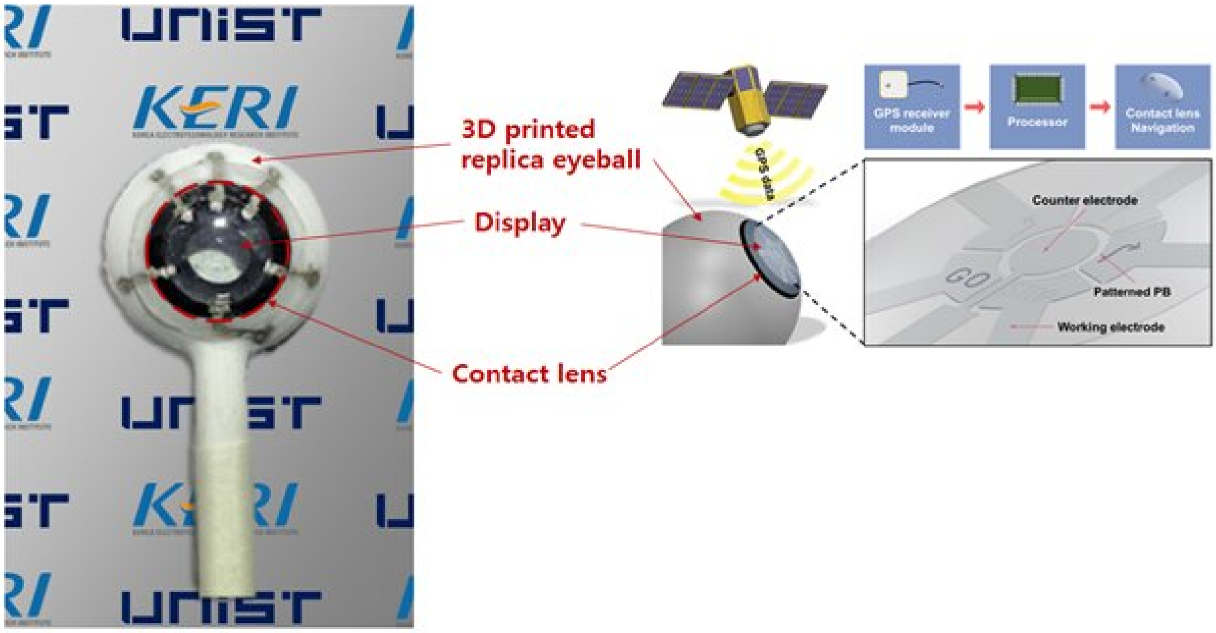


Image presents a schematic of the PB-based EC display with a navigation function in an AR smart contact lens that shows directions to the destination to a user on the EC display by receiving GPS coordinates in real time. Credit: Korea Electrotechnology Research Institute

Image showing meniscus phenomenon. Credit: Korea Electrotechnology Research Institute

Dr. Seol Seung-Kwon's of KERI said, "Our achievement is a development of 3D printing technology that can print functional micro-patterns on non-planner substrate that can commercialize advanced smart contact lenses to implement AR." He added, "It will greatly contribute to the miniaturization and versatility of AR devices."

The related research results were recently published as a cover article in *Advanced Science*.

The research team believes that this achievement will attract a lot of attention from companies related to batteries and biosensors that require micro-patterning of Prussian blue as well as the AR field, and plans to find related demand companies and promote technology transfer.

More information: Je Hyeong Kim et al, Meniscus-Guided Micro-Printing of Prussian Blue for Smart Electrochromic Display, *Advanced Science* (2022). DOI: 10.1002/advs.202205588

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