



## Commentary

## Precisely integrated contact lens: An intraocular pressure guard for glaucoma patients

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### ABSTRACT

Recently, scientists at Pohang University of Science and Technology in South Korea constructed a smart theranostic contact lens. The highly integrated smart contact lens is composed of an intraocular pressure (IOP) biosensor, a drug delivery system (DDS), a wireless communication system, as well as a circuit chip for IOP regulation. This design provides a new opportunity for wearable medical treatment in the individualized treatment of glaucoma and other ocular diseases.

From contact lenses to the ocular disease therapy, the bold innovation of researchers has promoted the rapid development of smart diagnosis and treatment integration [1,2]. During the development, metallic materials such as copper films have been used to construct IOPs [1]. Nowadays, constructing more advanced and convenient materials is of great interest. Professor Sei Kwang Hahn of Pohang University of Science and Technology is one of the world's most prominent materials science and engineering scientists. He has innovatively proposed an accurately integrated “smart theranostic contact lens”, and further expanded its biomedical application. As described in Nature communications [3], Hahn and his team applied gold hollow nanowires (AuHNW) to construct sensitive and stable sensors that rely on electrical signals to control the switch of the flexible DDS system releasing the drug for lowering the IOP.

Smart contact lens has emerged as the promising wearable medical device in the field of medical care [4,5]. Because intraocular pressure is closely related to human activities and circadian rhythm, long-term continuous tracking is more conducive to intraocular pressure monitoring. At present, continuous IOP monitoring systems such as smart contact lens tonometer based on pressure have attracted much attention [6]. In particular, the Triggerfish system was approved by the US Food and Drug Administration (FDA) in 2016 for monitoring IOP. However, this kind of smart contact lens still faces the challenge of single function, and although it has monitoring function, it can't meet the on-demand drug delivery [7]. In addition, drug-eluting contact lenses as drug reservoirs can reduce IOP by improving the bioavailability [8]. However, the lack of biocompatibility and long-term monitoring function limit its further application. In the latest issue of Nature Communications, Kim et al. of Hahn group introduced a smart contact lens with integrated diagnosis and treatment, which could monitor intraocular pressure

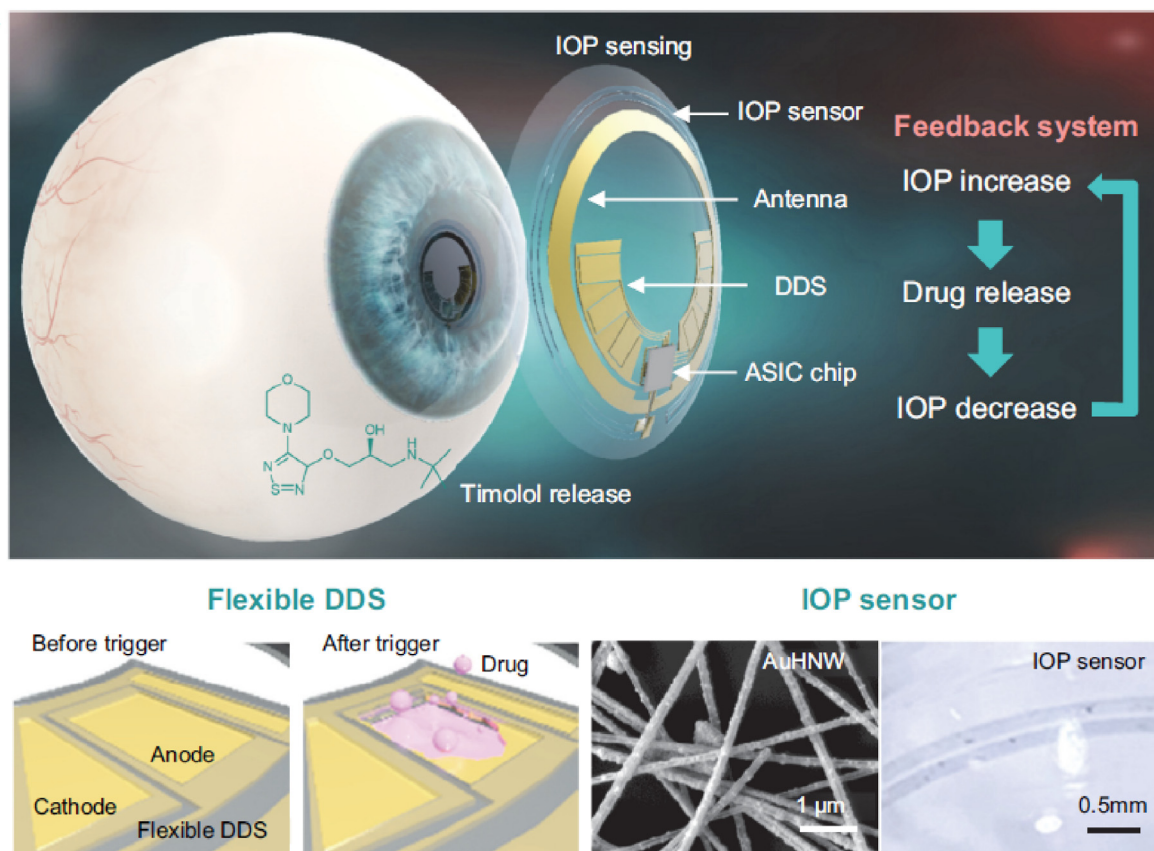
changes with high sensitivity and deliver the drug in response to IOP [3].

As shown in Fig. 1, this work was based on Hahn team's previous work on smart contact lenses. The IOP sensor with AuHNW, flexible DDS, wireless circuit and circuit chip were highly integrated on the plane of xylene C substrate. AuHNW was composed of 20–30 nm thick gold shell and Ag core, which possessed unique sensitivity, high light transmittance and chemical stability. Additionally, PEDOT: PSS polymers [9] which contained d-sorbitol, was used to fill the blank cave in the micro-AuHNW network and keep the conductivity of microstructure for long-term wireless monitoring of IOP. When the IOP was higher than the normal value, the flexible DDS acts as the drug reservoir of timolol, and drug can be released on-demand through gold-channel electrochemical dissolution. In this study, the biological safety of ingenious contact lenses has been studied by live/dead cell experiments and corneal injury analysis experiments. In addition, the feasibility of the contact lens for monitoring and controlling IOP was confirmed by treating glaucoma rabbits as the research object. Finally, the structural integrity of retina and the analysis of biomarkers also proved its therapeutic effect. This innovative design provided the possibility for personalized treatment of glaucoma.

Currently, nanomaterials such as graphene [10], AgNW and silicon [4] have been investigated for the preparation of multifunctional contact lenses. Kim et al. selected the gold hollow nanowires with high transparency due to the surface plasmon resonance effect as the IOP sensor. AgHNW nanowires were more prone to fracture than bulk nanowires under applied strain with high sensitivity and reasonable tensile capacity [3]. Furthermore, AgHNW was an excellent candidate for clinical applications due to its inherent biocompatibility and chemical characterization without passivation. The work of Kim et al. opened up a new avenue for personalized treatment of glaucoma with a high degree of centralized

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**Fig. 1.** A diagnostic contact lens for intraocular pressure monitoring and intelligent drug delivery in glaucoma patients. Reproduced with permission [3]. Copyright 2022, Springer Nature.

diagnosis and treatment integration [3]. They continuously monitored the changes in the IOP using gold-hollow nanowires. At the same time, the flexible DDS system with high biocompatibility controlled the intraocular pressure by electrically triggering the release of sufficient drug reservoir. Since different glaucoma patients have development processes, various patients should be provided with specific diagnosis and treatment. Smart contact lenses allow personalized treatment to be tailored to different targeted IOPs, ensuring therapeutic efficacy and reducing side effects. The strategy could also be used for blood glucose monitoring and treatment of diabetic retinopathy [11–13] and wireless immune-sensing of cortisol [14]. In the long term, the smart contact lens with real-time biological characteristic analysis and self-control treatment property can realize wide application in the wearable health care field. The promising strategies provided by this intelligent diagnosis and treatment system will actively promote the emergence of a new generation of personalized health management treatment systems.

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