# Precisely integrated contact lens

Ran, Meixin; Yan, Jiaqi; Zhang, Hongbo

*Published in:*
Biomedical Technology

*DOI:*
10.1016/j.bmt.2023.03.001
10.1016/j.bmt.2023.03.001

Published: 01/12/2023

*Document Version*
Final published version

*Document License*
CC BY

Link to publication

*Please cite the original version:*
Ran, M., Yan, J., & Zhang, H. (2023). Precisely integrated contact lens: An intraocular pressure guard for glaucoma patients. *Biomedical Technology*, *4*, 39-40. https://doi.org/10.1016/j.bmt.2023.03.001, https://doi.org/10.1016/j.bmt.2023.03.001

Biomedical Technology 4 (2023) 39–40

Contents lists available at ScienceDirect

Biomedical Technology

journal homepage: www.keaipublishing.com/en/journals/biomedical-technology

Commentary

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

Meixin Ran [a,b], Jiaqi Yan [a,b], Hongbo Zhang [a,b,*]

[a] Pharmaceutical Sciences Laboratory, Faculty of Science and Engineering, Åbo Akademi University, Turku, Finland
[b] Turku Bioscience Centre, University of Turku and Åbo Akademi University, Turku, Finland

## 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

* Corresponding author. Pharmaceutical Sciences Laboratory, Faculty of Science and Engineering, Åbo Akademi University, Turku, Finland.
*E-mail address:* hongbo.zhang@abo.fi (H. Zhang).

https://doi.org/10.1016/j.bmt.2023.03.001
Received 18 November 2022; Received in revised form 10 March 2023; Accepted 11 March 2023
Available online 31 March 2023

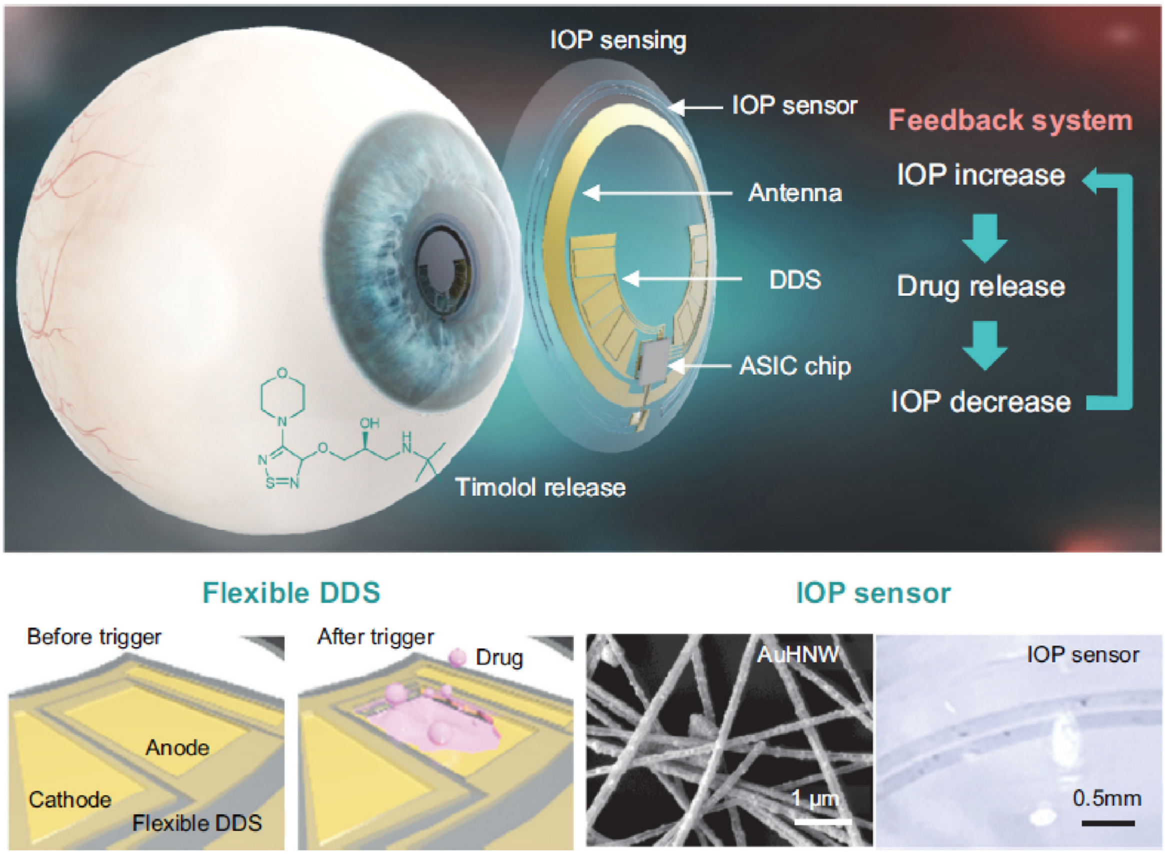


**Fig. 1.** A diagnostic contact lens for intraocular pressure monitoring and intelligent drug delivery in glaucoma patients. Reproduced with permission [3]. Copyright 2022, Springer Nature.

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.

## Declaration of competing interest

All authors declared that there are no conflicts of interest.

## Acknowledgments

We appreciated the financial support from the research Fellow (Grant No. 353146), project (347897), solutions for Health Profile (336355), InFLAMES Flagship (337531) grants from Academy of Finland; and the Finland China Food and Health International Pilot Project funded by the Finnish Ministry of Education and Culture (No. 280M0052K1). Meixin Ran (CSC202207960005) and Jiaqi Yan (CSC202107960001) were sponsored by the China Scholarship Council.

## References

[1] C. Yang, et al., Intelligent wireless theranostic contact lens for electrical sensing and regulation of intraocular pressure, Nat. Commun. 13 (1) (2022) 2556.
[2] Y. Zhu, et al., Lab-on-a-Contact lens: recent advances and future opportunities in diagnostics and therapeutics, Adv. Mater. 34 (24) (2022), 2108389.
[3] T.Y. Kim, et al., Wireless theranostic smart contact lens for monitoring and control of intraocular pressure in glaucoma, Nat. Commun. 13 (1) (2022) 6801.
[4] J. Kim, et al., A soft and transparent contact lens for the wireless quantitative monitoring of intraocular pressure, Nature Biomedical Engineering 5 (7) (2021) 772–782.
[5] H. Luo, B. Gao, Development of smart wearable sensors for life healthcare, Engineered Regeneration 2 (2021) 163–170.
[6] J. Kim, E. Cha, J.U. Park, Recent advances in smart contact lenses, Advanced Materials Technologies 5 (1) (2019).
[7] J. Zhang, et al., Smart soft contact lenses for continuous 24-hour monitoring of intraocular pressure in glaucoma care, Nat. Commun. 13 (1) (2022) 5518.
[8] J. Xu, et al., Co-delivery of latanoprost and timolol from micelles-laden contact lenses for the treatment of glaucoma, J. Contr. Release 305 (2019) 18–28.
[9] J. Yu, et al., Fiber-shaped triboiontronic electrochemical transistor, Research (2021), 9840918, 2021.
[10] Z. Liu, et al., An ultrasensitive contact lens sensor based on self-assembly graphene for continuous intraocular pressure monitoring, Adv. Funct. Mater. 31 (29) (2021), 2010991.
[11] G.H. Lee, et al., Smart wireless near-infrared light emitting contact lens for the treatment of diabetic retinopathy, Adv. Sci. 9 (9) (2022), e2103254.
[12] Keum, D.H., et al., Wireless smart contact lens for diabetic diagnosis and therapy. Sci. Adv.. 6(17): p. eaba3252.
[13] S.K. Kim, et al., Bimetallic nanocatalysts immobilized in nanoporous hydrogels for long-term robust continuous glucose monitoring of smart contact lens, Adv. Mater. 34 (18) (2022), e2110536.
[14] Ku, M., et al., Smart, soft contact lens for wireless immunosensing of cortisol. Sci. Adv.. 6(28): p. eabb2891.