

Welcome Message

It is my great pleasure as a representative of the organizing committee to offer a warm greeting to the 18th IEEE International Conference on Nano/Micro Engineered and Molecular Systems (IEEE NEMS 2023), taking place at the Ramada Plaza Hotel Jeju, Jeju, Korea from May 14th to 17th, 2023.

This renowned conference attracts attendees from all over the world to share their professional experiences, expand their networks, and stay up-to-date with the latest scientific and technological advancements in the fields of MEMS, nanotechnology, and molecular technology.

The conference program will include plenary and keynote lectures, invited talks, and oral and poster presentations, providing excellent opportunities for meaningful discussions and networking with distinguished researchers. I strongly encourage all participants to take full advantage of the program and establish long-lasting connections.

I would like to express my sincere gratitude to the members of the organizing and program committees, the advisory committee, and the sponsors for their generous support and commitment, without which this conference would not be possible.

Jeju Island, our conference venue, is a UNESCO world natural heritage site, offering a unique setting with a diverse range of natural wonders, including islands, volcanos, waterfalls, beaches, national parks, caves, and forests.

I hope you will have a productive and enjoyable conference experience, and I am confident that this conference will be academically enriching, socially rewarding, and unforgettable for all delegates and accompanying persons. Please take advantage of your time in Jeju to enjoy the conference and social activities to the fullest.

Thank you for attending and welcome to IEEE NEMS 2023.

Inkyu Park

General Chair of IEEE NEMS 2023

KAIST Chair Professor



- [P1-126] **Polystyrene Microplastic Penetrates Across the Blood-brain Barrier(BBB) and is Dysfunctional of Tricatures Cells**
Yeong Seon Cho, Jonghoon Choi, and Hong Nam Kim
¹Korea Institute of Science and Technology, Korea, ²Chung-Ang University, Korea
- [P1-127] **Modification of Functional Groups onto 4H-SiC Surface for Application of Biochemical Sensor**
Sung-Woong Han, Dong-Eun Kim, Seongjun Kim, Min-Jae Kang, and Hoon-Kyu Shin
Pohang University of Science and Technology, Korea
- [P1-128] **SU-8 Cantilever Integrated with Doped Silicon Strain Sensor for Improving the Force Sensitivity**
Hadan Sun, Dong-Su Kim, Yun-Jin Jeong, Jong-Yun Kim, and Dong-Weon Lee
Chonnam National University, Korea
- [P1-130] **Highly Sensitive Stress Biomarker Detection by Polypyrrole Nanotube Coupled Field-Effect Transistor**
Gyeong-Ji Kim and Oh Seok Kwon
Sungkyunkwan University, Korea
- [P1-131] **Toxicity Screening on Zebrafish(Diano Rerio) Embryos and Larvae**
Ji Sun park¹ and Oh Seok kwon²
¹Korea Research Institute of Bioscience and Biotechnology, Korea,
²Sunkyunkwan University, Korea
- [P1-132] **Detection of Dopamine Exocytosis Using Liquid-ion Gated Field-effect Transistor Aptasensor with High Sensitivity**
Lina Kim¹ and Oh Seok Kwon²
¹Korea Research Institute of Bioscience and Biotechnology, Korea,
²Sunkyunkwan University, Korea
- [P1-133] **Experimental Study on Bubble Dynamics in a Narrow Gap – parallel Plates and Cylindrical Gap**
Y. S. Kannan¹ and Badarinath Karri²
¹Chaitanya Bharati Institute of Technology, India, ²Indian Institute of Technology Hyderabad, India
- [P1-134] **Nanomesh Electrodes for the Plant-Compatible Electronics**
Kiwook Hwang¹, Sungha Jeon¹, Jiwon Hong¹, Minsu Choi¹, Jinwoo Yeo¹, Sunghoon Lee², Soohwan Song¹, Takao Someya², Seong Jun Park¹, and Jae Joon Kim³
¹Korea Advanced Institute of Science and Technology, Korea, ²The University of Tokyo, Japan, ³Electronics and Telecommunications Research Institute, Korea
- [P1-135] **Cell Behavior Affected by Gradient Microenvironment Structures Fabricated Laser Direct Lithography (LDL)**
Daekyeong Jung¹, Donggee Rho¹, Yoomin Park¹, Namho Bae¹, Taejae Lee¹, Moonkeun Lee¹, Sukjae Lee¹, Hyungjun Lim², and Kyoung G. Lee¹
¹National NanoFab Center, Korea, ²Korea Institute of Machinery and Materials, Korea

SU-8 Cantilever Integrated with Doped Silicon Strain Sensor for Improving the Force Sensitivity

Haolan Sun, Dong-Su. Kim, Yun-Jin Jeong, Jong-Yun Kim and Dong-Weon Lee

Abstract — Cardiovascular disease (CVD) is the number one cause of death in humans, but the development of new drugs is a lengthy process. Measuring contraction force of cardiomyocytes (CMs) is desirable to quantify drug toxicity to effectively develop drugs. For detecting the contraction force of CMs, integrated strain sensor cantilevers have been proposed which offer advantages like real-time monitoring and non-invasive measurements. However, metal strain sensors have limited sensitivity. In this research, it is addressed by a SU-8 cantilever with a doped silicon strain sensor that shows high sensitivity in measuring contraction forces (below $1\mu\text{N}$). The doped silicon sensor is sandwiched within the SU-8 cantilever via transfer printing, allowing for the combination of the high sensitivity of silicon sensors with the mechanical flexibility and biocompatibility of the SU-8 cantilever. The doped silicon strain sensor shows a higher force sensitivity (17 times) than SU-8 cantilever with metal strain sensors. The device has potential applications in early-stage drug toxicity screening.

I. INTRODUCTION

According to the World Health Organization report, in 2019, 18.6 million deaths were attributed to cardiovascular diseases (CVD) globally. CVD represents 37% of deaths of individuals less than 70% (1). As a result, CVD have been a popular topic studied by researchers today, especially in the field of pharmacology. The main obstacle to drug development is drug-induced cardiotoxicity. Various heart-on-a-chip devices have been developed to address the limitations of traditional in vitro drug testing. Polymer cantilevers integrated with metal strain sensor can directly measure the contraction force of cardiomyocyte in real-time. Integrating strain sensor with flexible cantilever meets the requirement for high throughput and facilitates effective long-term drug testing. However, the low sensitivity of metal strain sensor limits its application in this field (3, 4). Therefore, developing cantilever with high sensitivity is highly desired to improve the reliability of conventional drug screening methods.

II. DESCRIPTION OF THE NEW METHOD OR SYSTEM

The basic idea of the device is to use doped silicon as the sensor element, with silicon integrated in the SU-8 cantilever in a sandwich structure. Although the use of silicon is limited by its high Young's modulus, the high piezoresistive effect of doped silicon greatly improves the sensitivity and linearity of contraction force detection. Figure 1 shows the change in resistance caused by the force

apply to the free end of the cantilever in a finite element analysis (COMSOL) simulation. The sensitivity of the SU-8 cantilever with doped silicon sensor is 17 times higher than that of the Au strain sensor. The proposed SU-8 cantilever is expected to be used in a real-time high-throughput screening system for cardiac drug toxicity screening.

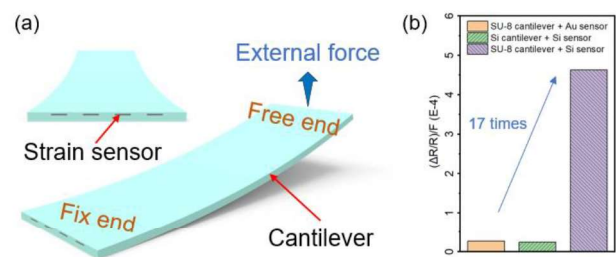


Figure 1. COMSOL-based force sensitivity comparison on different cantilevers and sensors.

The proposed cantilever is fabricated of SU-8. Compared with the commonly used PDMS, SU-8 compliance to photolithographic process, is optical transparent and has good biocompatibility to sustain long-term cell culture. The SU-8 cantilever has microgroove patterns on the surface. This pattern promotes longitudinal alignment of the cardiomyocytes and enhances their contractility and maturity. The doped silicon strain sensor is integrated inside the cantilever by transfer printing process. Fig. 2 shows the working principle of the SU-8 cantilever device. The resistance of the doped silicon strain sensor at the fixed end of the cantilever changes with the deformation of the cantilever. Through Wheatstone bridge circuit output as a voltage signal for detection.

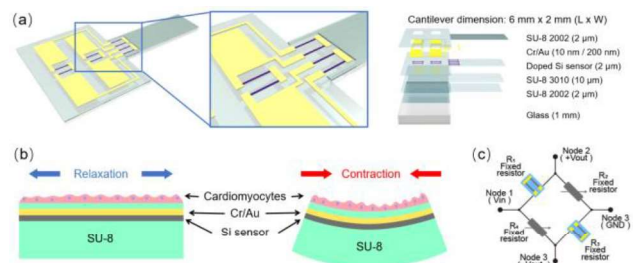


Figure 2. The design of SU-8 cantilevers with doped Si sensor: (a) Structural design of the device, Si sensors are integrated in SU-8 cantilever, (b) The working principle of SU-8 cantilever with doped Si sensors, The deformation of the cantilever results in a change in resistance of doped Si sensors. (c) Circuit arrangement of the doped silicon strain sensor.

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from MEMS and Nanotechnology Laboratory, School of Mechanical System Engineering, Chonnam National University, Gwangju, Korea.

Figure 3 shows the fabricating process of the SU-8 cantilever. The Fabrication is start at a glass wafer: (a) Prepare a glass wafer, (b) Prepare a PVA layer on the glass wafer as sacrificial layer, (c) Coating SU-8 2002 layer cover the PVA, (d) Fabricate SU-8 cantilever on the wafer, (e) transfer the silicon sensor from SOI wafer to SU-8 cantilever, (f) Deposit Cr/Au layer and define the wire connection by photolithography, (g) Coating SU-8 as isolation layer and define the groove pattern on it, (h) Remove the PVA and release the cantilever. In the whole fabrication process, the silicon sensor transfer is the most critical.

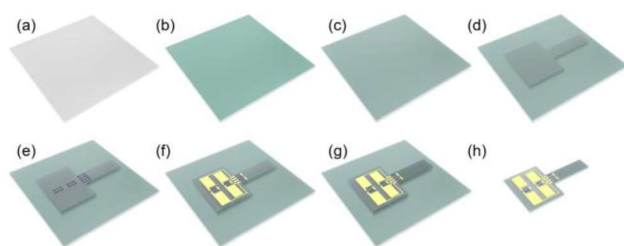


Figure 3. Fabricating process of SU-8 cantilever with Si sensor.

III. EXPERIMENTAL RESULTS

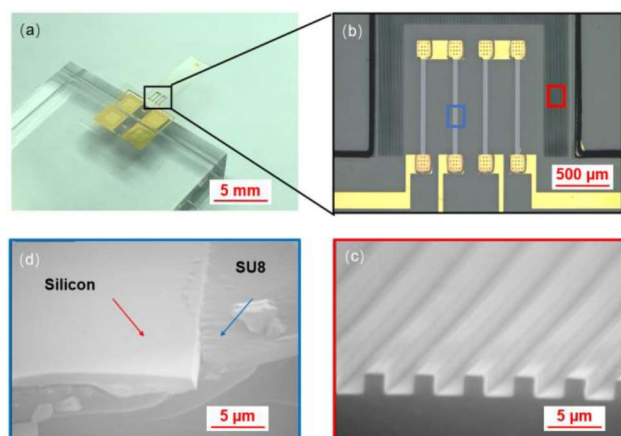


Figure 4. The images of SU-8 cantilever integrated with doped silicon strain sensor.

Figure 4 shows the SU-8 cantilever with doped silicon sensor: (a) the optical image of the SU8 cantilever, (b) the microscope image of the Si sensor on the SU8 cantilever with microgroove pattern, (c) the microscope image and (d) the SEM image of the microgroove structure.

The experimental setup used to evaluate the cantilever characteristics is shown in Figure 5(a) and demonstrates the good linearity of the sensor in the displacement range from 0 to 100 μm. Even at small displacements (below 1 μm), a clear voltage signal change is detected as shown in Figure 5(b-d). The presented device was used for drug testing to validate its effectiveness. We used the proposed SU-8 cantilever integrated with a doped silicon strain sensor to detect the contraction force of cardiomyocytes under different drug concentrations. Figure 6 shows the changes in contraction force and beat frequency of the SU-8 cantilever integrated with the doped silicon sensor as a function of Verapamil.

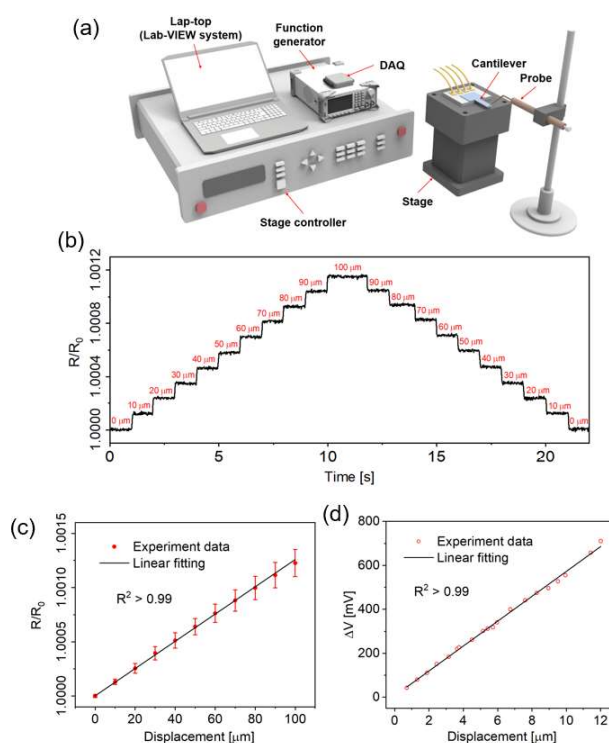


Figure 5. (a) Schematic diagram of measurement system. (b-d) Basic characteristic evaluation, resistance and output voltage as a function of cantilever displacement.

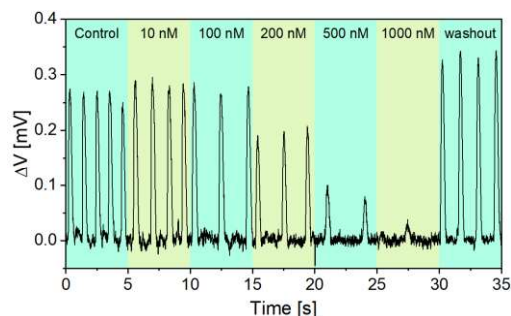


Figure 6. Change in output voltage of the SU-8 cantilever according to the different drug concentration (Verapamil).

ACKNOWLEDGMENT

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REFERENCES

- [1] Savoji, Houman, et al. "Cardiovascular disease models: a game changing paradigm in drug discovery and screening." *Biomaterials* 198 (2019): 3-26.
- [2] Cho, Kyoung Won, et al. "Sensors in heart-on-a-chip: A review on recent progress." *Talanta* 219 (2020): 121269.
- [3] Kim, Dong-Su, et al. "Piezoresistive sensor-integrated PDMS cantilever: A new class of device for measuring the drug-induced changes in the mechanical activity of cardiomyocytes." *Sensors and Actuators B: Chemical* 240 (2017): 566-572.
- [4] Dong, Mingming, et al. "Real-Time Monitoring of Changes in Cardiac Contractility Using Silicon Cantilever Arrays Integrated with Strain Sensors." *ACS sensors* 6.10 (2021): 3556-3563.

SU-8 Cantilever Integrated with Doped Silicon Strain Sensor for Improving the Force Sensitivity

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Abstract

Cardiovascular disease (CVD) is the number one cause of death in humans, but the development of new drugs is a lengthy process. Measuring contraction force of cardiomyocytes (CMs) is desirable to quantify drug toxicity to effectively develop drugs. For detecting the contraction force of CMs, integrated strain sensor cantilevers have been proposed which offer advantages like real-time monitoring and non-invasive measurements. However, metal strain sensors have limited sensitivity. In this research, it is addressed by a SU-8 cantilever with a doped silicon strain sensor that shows high sensitivity in measuring contraction forces (below 1 μ N). The doped silicon sensor is sandwiched within the SU-8 cantilever via transfer printing, allowing for the combination of the high sensitivity of silicon sensors with the mechanical flexibility and biocompatibility of the SU-8 cantilever. The doped silicon strain sensor shows a higher force sensitivity (17 times) than SU-8 cantilever with metal strain sensors. The device has potential applications in early-stage drug toxicity screening.



MEMS & Nanotechnology Laboratory



Introduction

Background

- Assessment of drug toxicity by measuring changes in CMs contraction force is an intuitive and effective method.
- Cantilevers integrated with strain sensor are used for measuring the contraction force of CMs.

Claims and proposal

type	 Metal strain sensor	 CB:TPU strain sensor	 Creak sensor
Drawback	low sensitivity, unstable	low sensitivity, difficult to miniaturize	Nonlinear property

- For improving the sensitivity and linearity of measuring CMs contraction force, a doped silicon strain sensor is combined with SU-8 cantilever.
- SU-8 cantilevers integrated with doped silicon strain sensors are used to detect changes in the CMs contraction force under treatment with different drug concentrations.

Design and Fabrication

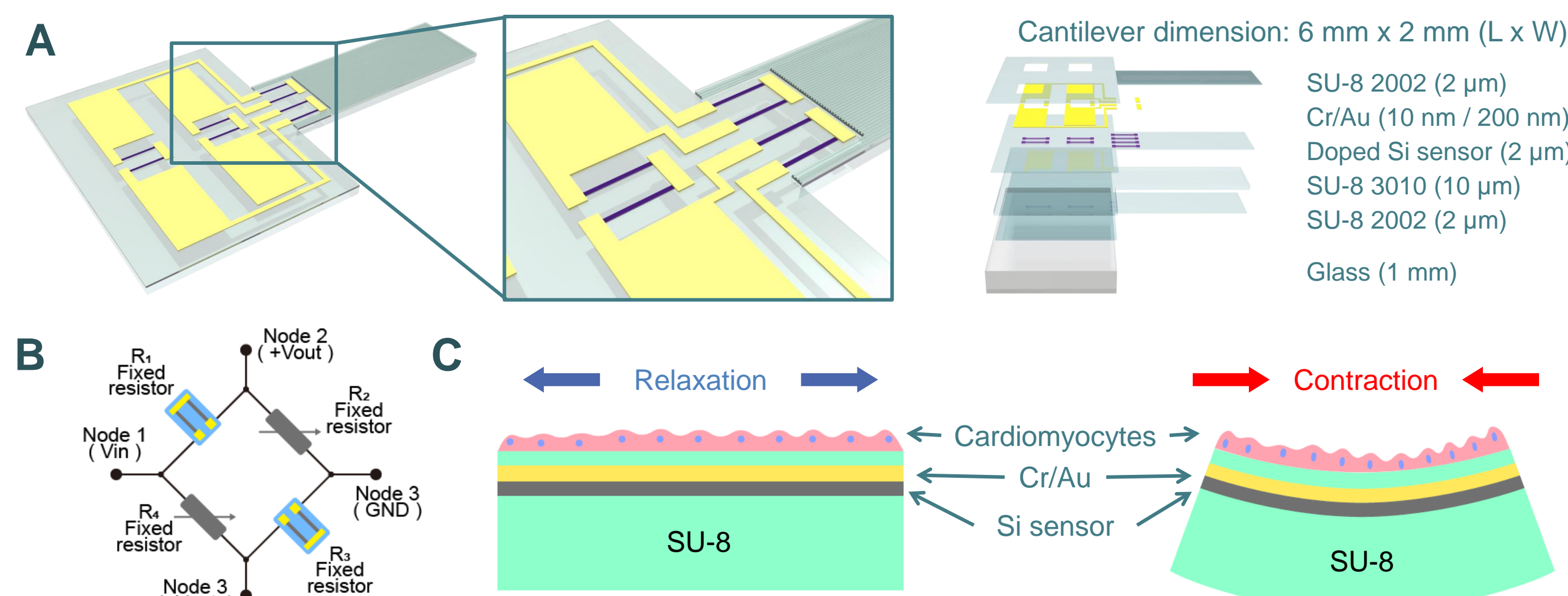


Fig.1 SU-8 cantilever integrated with doped silicon strain sensor. (A) schematic shows the SU-8 cantilever with doped silicon strain sensor. (B, C) Working principle of the silicon strain sensor. The contraction of Cardiomyocytes cause the bending of the silicon strain sensor.

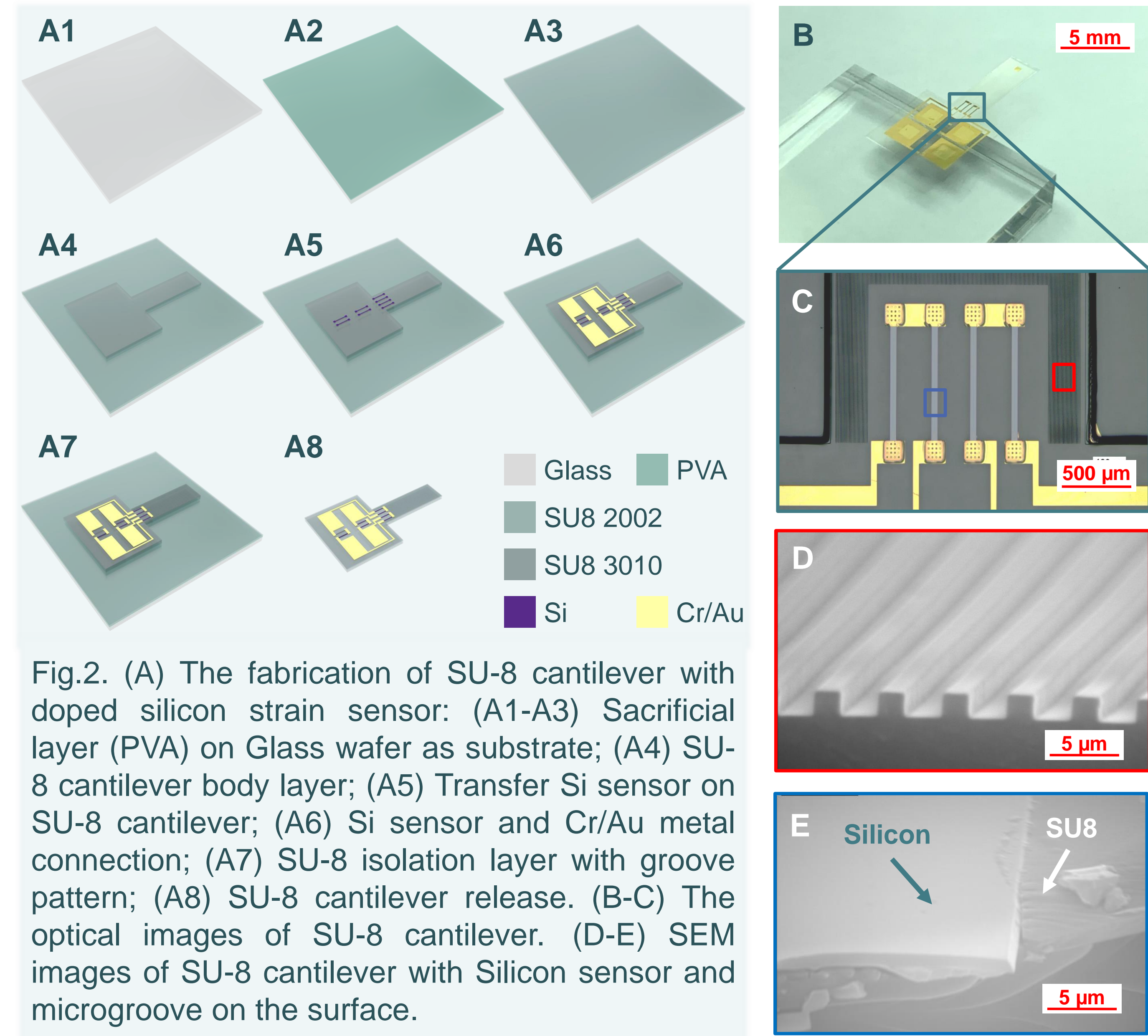


Fig.2. (A) The fabrication of SU-8 cantilever with doped silicon strain sensor: (A1-A3) Sacrificial layer (PVA) on Glass wafer as substrate; (A4) SU-8 cantilever body layer; (A5) Transfer Si sensor on SU-8 cantilever; (A6) Si sensor and Cr/Au metal connection; (A7) SU-8 isolation layer with groove pattern; (A8) SU-8 cantilever release. (B-C) The optical images of SU-8 cantilever. (D-E) SEM images of SU-8 cantilever with Silicon sensor and microgroove on the surface.

Experiment

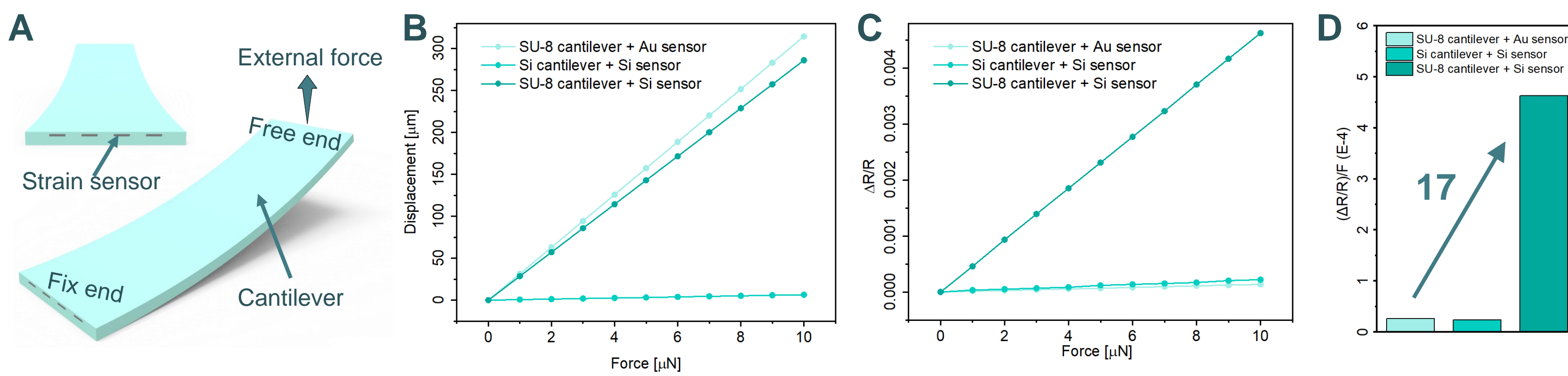


Fig.3 High force sensitivity of SU-8 cantilever integrated with doped silicon strain sensor. (A). The mold using at the FEA. (B) The comparison of cantilever's free end displacement. (C) Resistance changes with increasing external force. (D) The force sensitivity comparison between different mold.

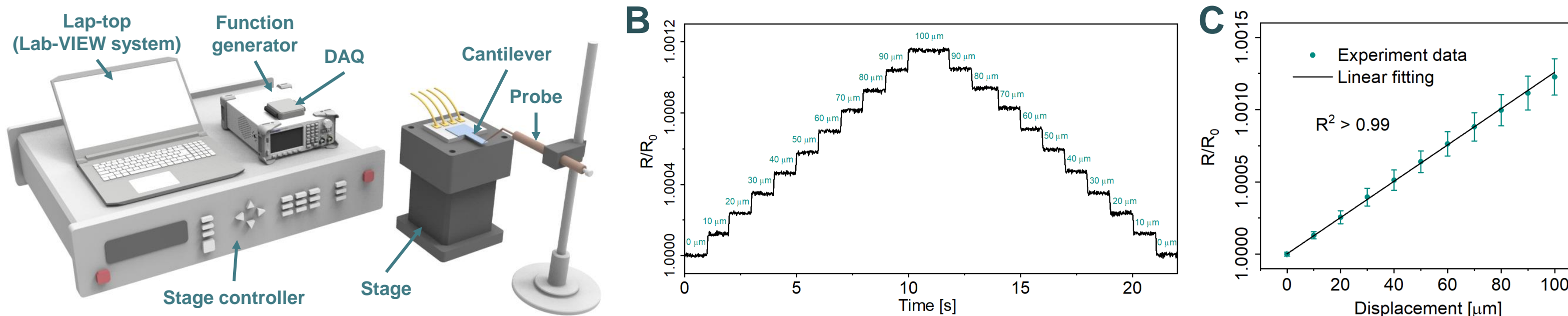


Fig.4 (A) Probe system for testing device characteristics. (B) Resistance changes plotted as functions of applied displacement. (C) Linear plot of the resistance variation as a function of displacement.

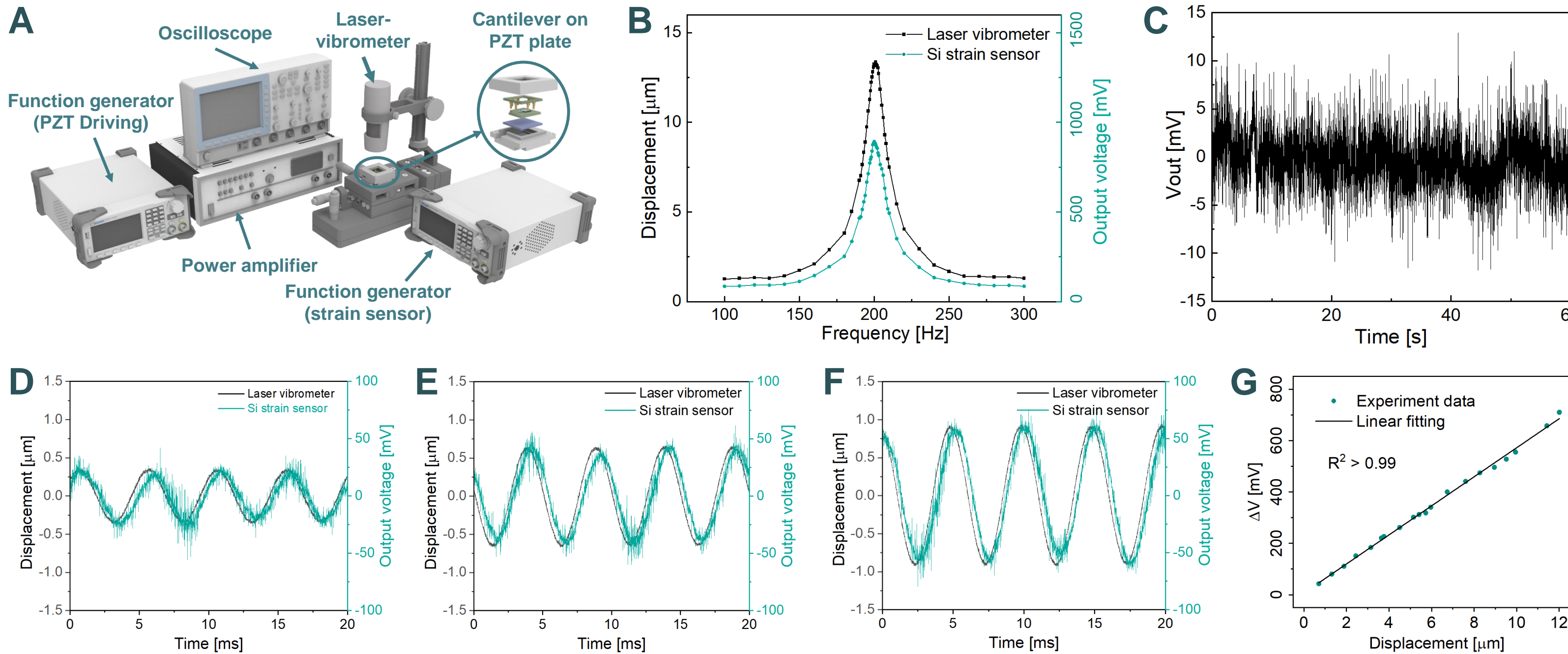


Fig.5 (A) PZT system for testing device characteristics. (B) Frequency of SU-8 cantilever integrated with doped silicon strain sensors. (C) Output voltage of silicon strain sensor in air. (D-F) Change in output voltage for different applied displacements of 0.6, 1.2, and 1.8 μ m, respectively. (G) Linear plot of the change in output voltage with respect to an applied displacement from 0 to 10 μ m.

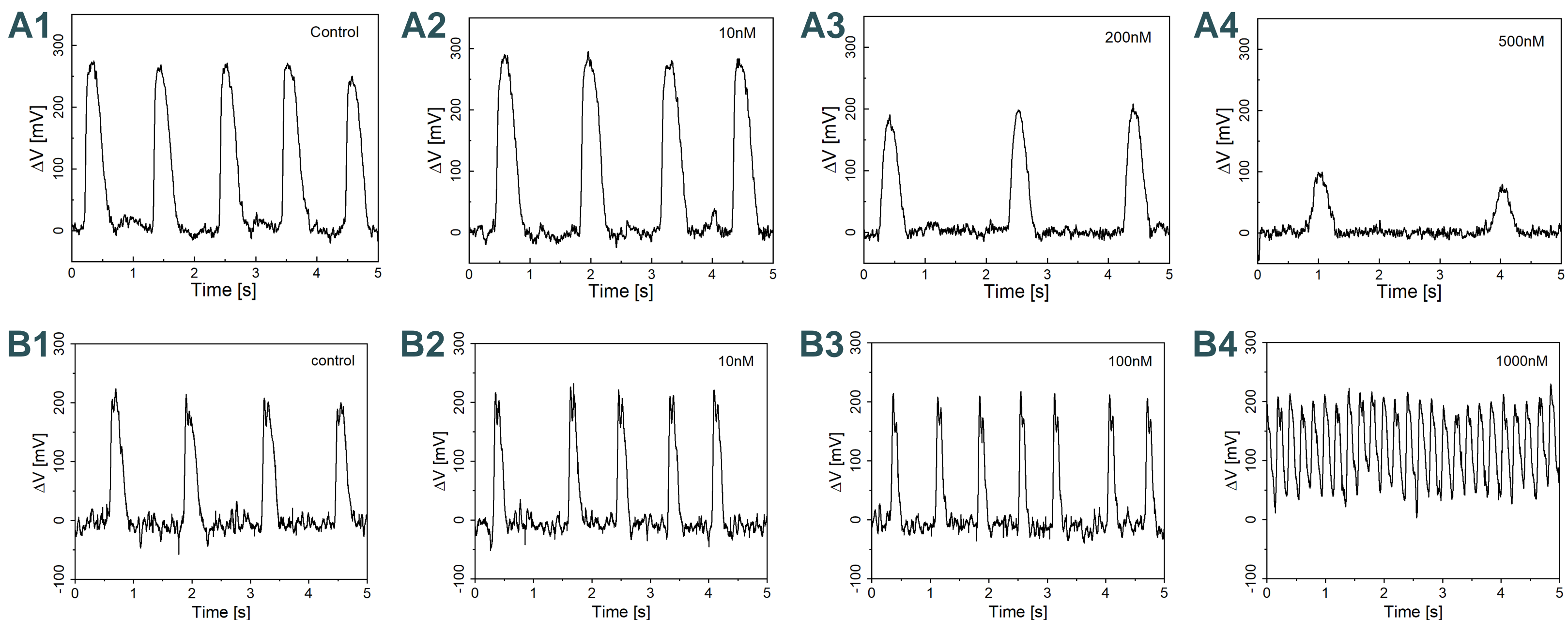


Fig.6 Representative real-time traces of the Si strain sensor output owing to the contraction and relaxation of cardiomyocytes treated with different drugs: (A) Verapamil, (B) Isoproterenol.

Reference

- [1] Lind, Johan U., et al. "Instrumented cardiac microphysiological devices via multimaterial three-dimensional printing." *Nature materials* 16.3 (2017): 303-308.
- [2] Kim, Dong-Su, et al. "Highly durable crack sensor integrated with silicone rubber cantilever for measuring cardiac contractility." *Nature Communications* 11.1 (2020): 535.

Conclusion

This research presents the design and characterization of an SU-8 cantilever with an integrated doped silicon strain sensor that provides a high piezoresistive coefficient to improve the sensitivity of cardiomyocyte contraction force detection. The doped silicon strain sensor outperforms metal strain sensors by increasing the force detection limit by 17 times, enabling the detection of tiny forces below 1 μ N. The proposed device was used to study the effect of verapamil and isoprenaline on the contractile properties of cardiomyocytes, demonstrating its potential as an early predictor of cardiotoxic compounds in analytical drug discovery.

Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1A5A8018367 and RS-2022-00165505)