The 23rd Korean MEMS Conference

제23회 한국 MEMS 학술대회

2021.04.07(수) ~ 04.09(금), 부여 롯데리조트

| 논문원고접수 |

2020년 12월 14일(월) ~ 2021년 1월 13일(수)

| 논문심사결과 통보일 |

2021년 2월 17일(수)까지 홈페이지 (http://www.micronanos.org)에 공지 및 책임저자에게 이메일로 통보

| 초록 및 논문접수처 |

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| 논문범위 |

1. Materials, Fabrication, Packaging and Simulation Technologies
2. Micro/Nanofluidics
3. Bio/Medical Micro/Nano Devices
4. Physical and Mechanical Micro/Nano Sensors and Systems
5. Chemical and Environmental Sensors
6. RF/Optical Devices
7. Micro/Nano Energy and Power Devices
8. Soft, Flexible and Printed Devices

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논문 No.	Journal Title	First Author	Corresponding Author	Presenting Author	Organization
TP-2-22	효율적인 광 흡수를 통하여 가역적 NO2 감지가 가능한 MoS2가 통합된 LED	박준	최정욱	박준	영남대학교
TP-2-23	초저전력 광촉매식 마이크로 LED 가스 센서의 제작	이기철	박인규	이기철	한국과학기술원
TP-2-24	양극산화알루미늄 기판을 이용한 저전력 마이크로 히터 플랫폼 기반 가스센서 설계	이병주	박인규	이병주	한국과학기술원
TP-2-25	Characterization of Reduced Graphene Oxide based Hybrid Electrode Materials for Highly Sensitive Hydrogen Peroxide Determination	김호성	이이재	김호성	한국과학기술연구원
TP-2-26	Study on the Functionalization of SiC Surface for a Biochemical Sensor	한성웅	한성웅	한성웅	포항공과대학교
TP-2-27	A Low-cost, Wireless, and Portable Potentiostat for Cyclic Voltammetry 순환 전압전류법을 위한 저비용, 무선 및 휴대용 전위차계	김준우	김정현	김준우	광운대학교
TP-2-28	Fabrication and Characterization of a Thin Carbon Film as a Quasi-Reference Electrode for Miniaturized Electrochemical Biosensor Applications	피쥬스쿤두	신흥주	피쥬스쿤두	울산과학기술원
TP-2-29	요산 및 pH 동시 모니터링을 위한 MXene 기반 웨어러블 땀 패치센서	김현식	박재영	선우수경	광운대학교
TP-2-30	땀 속의 중금속 아연 이온 모니터링을 위한 Laser Induced Graphene 기반의 유연 패치 센서	Xue Hui	박재영	신영도	광운대학교
TP-2-31	CEA 바이오마커 조기 검출을 위한 3D 다공성 그래핀 기반의 유연 면역센서	Md Abu Zahed	박재영	윤상혁	광운대학교
TP-2-32	A highly sensitive MEMS acetone gas sensors with low power consumption for Diet-monitoring applications	이재은	이대식	이대식	한국전자통신연구원/UST

Poster Session 3 (FP-3)

4월 9일 금요일
09:00~10:10

논문 No.	Journal Title	First Author	Corresponding Author	Presenting Author	Organization
FP-3-01	회전 웅집 마이크로렌즈 어레이를 이용한 통증 평가용 3차원 얼굴 이미징 Stereoscopic Facial Imaging for Pain Assessment using Rotational Offset Microlens Arrays	권재명	정기훈	권재명	한국과학기술원
FP-3-02	Real-time Handheld Confocal Microscope using High Definition High Frame Rate Lissajous scanning MEMS Mirror	전재훈	정기훈	전재훈	한국과학기술원
FP-3-03	Flexible Serotonin Sensor with Electrochemically Deposited Graphene Oxide/PEDOT:PSS Composite for Neurochemical Imbalance Monitoring	고승현	이이재	고승현	한국과학기술연구원
FP-3-04	망막하 자극을 위한 패럴린 기반의 반구형 마이크로전극	홍예지	김소희	홍예지	대구경북과학기술원
FP-3-05	복제 몰딩을 이용한 PDMS 기반 마이크로 렌즈 어레이 제작	최희원	김용권	최희원	서울대학교
FP-3-06	A microstructured substrate for the dynamic culture of bioprinted cell-hydrogel constructs	이기현	박제균	이기현	한국과학기술원
FP-3-07	고대비 근적외선 영역 삼차원 얼굴 영상을 위한 초박형 라이트 필드 카메라	배상인	정기훈	배상인	한국과학기술원
FP-3-08	감염성 바이러스 신속 검출을 위한 시료 전처리 자동화 시스템 및 전기화학 센서 개발	허웅	정효일	허웅	연세대학교
FP-3-09	미세-유체 기반의 사출성형 칩을 이용한 극소농도의 균액에 적합한 항생제 감수성 검사 시스템	황순재	최정일	황순재	국민대학교
FP-3-10	세포 배양액 상태에 따른 심근세포 수축력 변화	김종윤	이동원	김종윤	전남대학교
FP-3-11	VOC 분석을 위한 가스 농축기의 개발 및 농축 성능 평가	강혜림	이국녕	강혜림	한국전자기술연구원
FP-3-12	Improving the Maturity of the Cardiomyocytes using Diaphragm-based Mechanical Stimulation	Abdullah-Bin Siddique	이동원	Abdullah-Bin Siddique	전남대학교
FP-3-13	형광 이미징을 위한 초박형 고속 오프셋 어레이드 카메라	김현경	정기훈	김현경	한국과학기술원
FP-3-14	nanoFET 바이오센서의 동작원리 설명 및 가짜 신호 해석	강혜림	이국녕	강혜림	한국전자기술연구원
FP-3-15	Analysis of Bacterial Inoculum Effect by using Microscopic imaging in micropatterned biochip	황정호	최정일	최정일	국민대학교
FP-3-16	세포 소기관 유래에 따른 엑소좀 모사 나노소포의 다양성	이현진	박재성	이현진	포항공과대학교

Improving the Maturity of the Cardiomyocytes using Diaphragm-based Mechanical Stimulation

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다이아프램 기반의 기계적 자극을 이용한 심근세포의 성숙도 향상

[1]압둘라 빈 시디 크, 김종윤, 이동원*,
전남 대학교 기계 시스템 공학부 MEMS 및 나노 기술 연구실, 광주, 61186

Abstract

Mechanical stimulation can enhance cardiac cell maturation and promotes intercellular communications. We propose a novel bio-compatible PDMS diaphragm for real-time monitoring of applied mechanical stimulation. The PDMS diaphragm consists of two different layers. The top layer contains nano-grooves that help to realize cells to be aligned in a single direction as well as elevate the connection between cells. The bottom layer contains a liquid metal strain gauge which is used for controlling the mechanical stimulation in real time and it doesn't show any crack formation even for large deformations. Mechanical stimulation is performed for 7 days and visible changes are observed between stimulated and control cells as sarcomere length and Cx43 expression has increased more in stimulated cells compared to control cells, indicating cell maturation. Moreover, the integrated strain gauge exhibits excellent stability even after long term mechanical stimulation which indicates it's suitability in various cell studies.

Keywords: ***Mechanical stimulation, Cardiac cell, PDMS diaphragm, Liquid metal, Strain gauge***

1. Introduction

Various artificial and nature-inspired processes are extensively investigated to better understand the effects of various stimulation techniques such as electrical, mechanical, electromechanical, long term culture, and biochemical on the maturation of cardiac cell [1].

Mechanical stimulation has been used as a maturation tool in many of the in vitro studies as mechanical stimulation can enhance the communication between cells and it impacts the overall action potential. In a study, it is revealed that cyclic stress can enhance contractile function, cell alignment and gene expression of cardiac cell along the stretch axis [2]. Nitsan et al. investigated the mechanical communication between two adjacent cell and found out that one cell can communicate with its neighbors mechanically through the deformation created on the surface by cell [3].

In this study, we have developed a novel stage top bio-reactor with nano-groove patterned PDMS diaphragm to monitor the cardiac cell behavior in real time. For better cell alignment, nano-groove was patterned on the PDMS surface. Another novelty of this device is the integration of liquid metal based strain gauge to monitor the mechanical stimulation with the help of change in resistance while capitalizing the liquid metal properties like flexibility and self-healing capability to negate any crack formation on the sensor due to larger deformation during mechanical stimulation.

2. Fabrication and Results

2.1 Fabrication

A simple PDMS diaphragm is fabricated to control and monitor the mechanical stimulation that is externally applied to the cell and real time monitoring is also a possibility using this platform. PDMS is used as the base material due to its bio compatibility and elastic nature as well as high light transmittance of the PDMS material is utilized here for the real time imaging and monitoring of the live growing cells. Galinstan based liquid metal strain sensor will be embedded into this device to remove the cracks that is usually created if solid metals are used on elastic materials. The whole fabrication is carried out in 3 different steps. In first step, nano-grooves are formed on top of a PDMS layer (thickness 80 µm) with the help of a PUA mold. Secondly, A PDMS layer (thickness 120 µm) with micro-channels (thickness 11.4 µm) is fabricated with the help of soft lithography and moulding processes. Then these 2 layers are plasma bonded together and then this bonded PDMS layers are again bonded with PDMS supporting structure for injection of Galinstan. After injection, these PDMS layers are attached to a pressure applying structure and a glass with the help of o_2 plasma bonder. Finally the PS ring is placed on top of the nano-groove layer. Optical and microscopic image of the fabricated liquid metal based sensor is illustrated in Figure 01.

2.2 Characterization

To characterize the fabricated sensors, pressure was applied and corresponding change in displacement, resistance and strain are observed. Figure 02 illustrates the effect of pressure on the resistance and change in displacement of integrated strain gauge as well as relationship between dc bias voltage of mechanical stimulator and corresponding pressure change. Pressure ranging between (27-160) mm Hg is applied by varying the dc bias and

corresponding change in displacement are observed (Figure 2a & 2b). For 6% change in strain, the diaphragm's change in displacement is found to be around 1.5 mm. To apply pressure, a customized pressure applying equipment is used and a pipe with diameter of 2mm was utilized as amount of pressure change can vary with the volume of the pipe and corresponding structure. Moreover, relation between displacement change and resistance is characterized in Figure 2c and it is observed that resistance changes linearly with a linearity factor of (R^2=0.98878) with the change of displacement till 1.3 mm but after that a slight change is observed due to the dimension constraint of the micro-channels. From Figure 2d, it is identified that resistance varies almost linearly (0.98859) with the change of strain and the curve shows the similar kind of trend as Figure 2c.

2.3 Results

To mature the cardiac cell, mechanical stimulation with frequency 1 Hz and duty cycle of 50% is applied for 7 days and this stimulation is controlled by the integrated liquid metal strain gauge. It is found that the fabricated sensor shows excellent stability even after 7 days of stimulation and the error margin is less that 1% which enables more precise control over mechanical stimulation. This is portrayed in Figure 3. To check the effect of mechanical stimulation on maturation of cardiac cell, the immunofluorescence staining is performed and difference in sarcomere length and connexin43 is observed between control and stimulated cells. It is observed that both sarcomere length and connexin43 expression has significantly increased in stimulated cell which is illustrated in Figure 4.

2.4 Conclusion

To conclude, a novel cell culture platform is introduced with integrated liquid metal strain gauge for monitoring and controlling of mechanical stimulation. The fabricated sensor exhibits excellent stable behavior even after long term mechanical stimulation. Moreover, stimulated cells are found to be more mature from immunofluorescence staining images in terms of sarcomere length and connexin43 expressions.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT & No.2017R1E1A1A01074550), South Korea.

References

1. Rachel R. Besser, Matthew Ishahak, Vera Mayo, Daniel Carbonero, Isabella Claure, Ashutosh Agarwal, Engineered Microenvironments for Maturation of Stem Cell-Derived Cardiac Myocytes, *Theranostics 8*, 01 (2018).
2. Lux M, Andrée B, Horvath T, Nosko A, Manikowski D, Hilfiker-Kleiner D, Haverich A, Hilfiker A., In vitro maturation of large-scale cardiac patches based on a perfusable starter matrix by cyclic mechanical stimulation, *Acta Biomater 30.*, (Jan. 2016).
3. Ido Nitsan, Stavit Drori, Shlomi Cohen and Shelly Tzlil1, Mechanical communication in cardiac cell synchronized beating, *Nature Physics 12*, 2016.

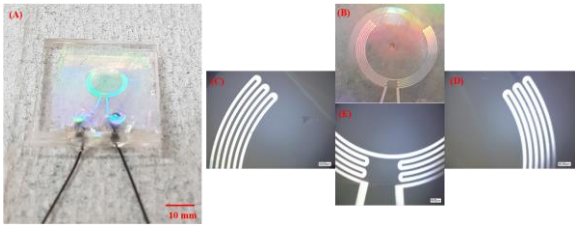

Fig. 1. Optical (a, b) & microscopic (c, d & e) image of fabricated liquid metal strain gauge

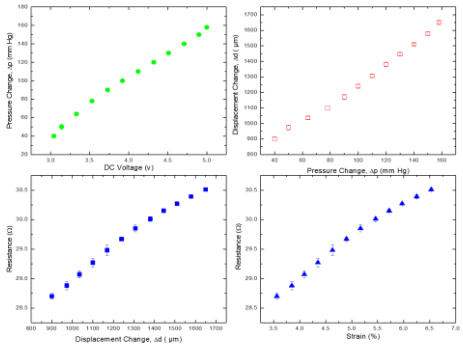

Fig. 2. Characterization of liquid metal based sensor (a) Relationship between applied dc bias voltage and corresponding pressure change, (b) Relationship between pressure change and change in displacement, (c) Relationship between displacement change and corresponding change in resistance & (d) Relationship between strain and corresponding change in resistance

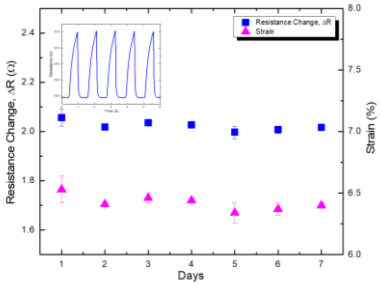

Fig. 3. Controlling and monitoring of mechanical stimulation with integrated liquid metal based strain gauge and it exhibits excellent stability even after 7 days of continuous stimulation

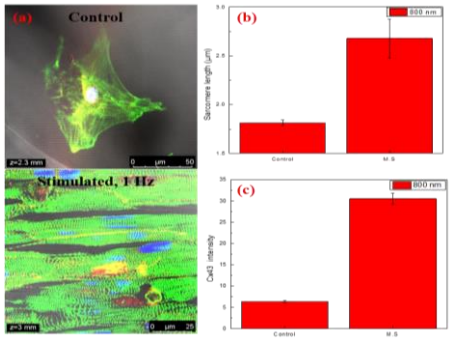

Fig. 4. Immunofluorescence experiment results with both presence and absence of external mechanical stimulation. (a) ICC protein expressions (nucleus-blue, α-actinin-green, and Cx43-red) & (b, c) Quantitative analysis of sarcomere length and Cx43 fluorescence intensity

Improving the Maturity of the Cardiomyocytes using Diaphragm-based Mechanical Stimulation

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Abstract

Mechanical stimulation can enhance cardiac cell maturation and promotes intercellular communications. We propose a novel bio-compatible PDMS diaphragm for real-time monitoring of applied mechanical stimulation. The PDMS diaphragm consists of two different layers. The top layer contains nano-grooves that help to realize cells to be aligned in a single direction as well as elevate the connection between cells. The bottom layer contains a liquid metal strain gauge which is used for controlling the mechanical stimulation in real time and it doesn't show any crack formation even for large deformations. Mechanical stimulation is performed for 7 days and visible changes are observed between stimulated and control cells as sarcomere length and Cx43 expression has increased more in stimulated cells compared to control cells, indicating cell maturation. Moreover, the integrated strain gauge exhibits excellent stability even after long term mechanical stimulation which indicates it's suitability in various cell studies.

◆ **Keywords :Mechanical stimulation, Cardiac cell, PDMS diaphragm, Liquid metal, strain gauge, Cell maturation**

System Setup For Mechanical Stimulation

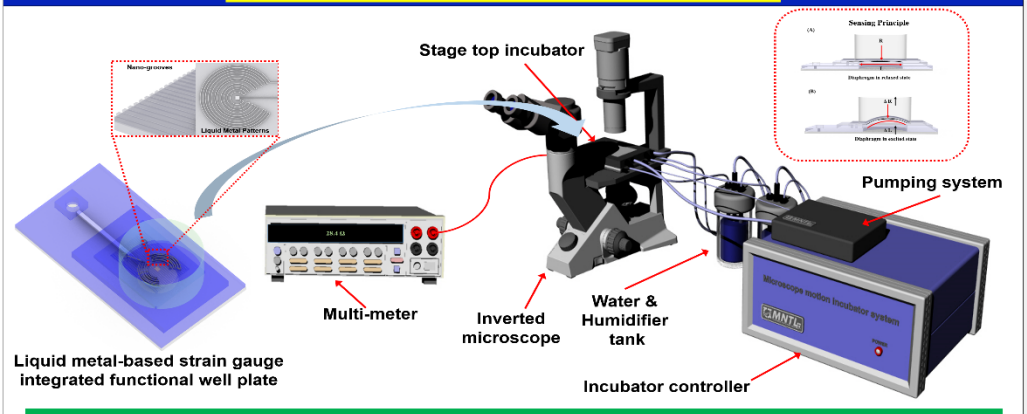

Fig.1 System setup for Mechanical stimulation with integrated liquid metal-based strain gauge and nano-grooves

Fabrication of Galinstan based sensor

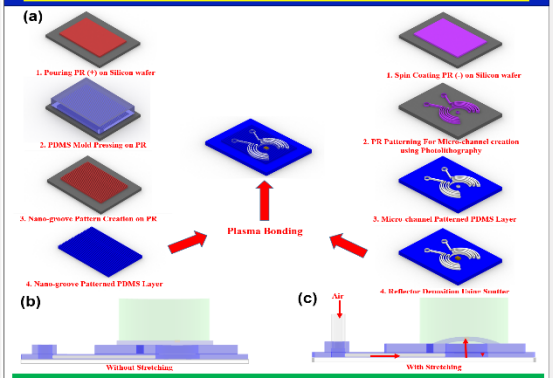

Fig.2 (a)Fabrication process flow of PDMS diaphragm with nano-grooves liquid-metal based strain gauge, (b) Diaphragm in relaxed conditions & (c) Diaphragm in stretched conditions

Cell Culturing Platform

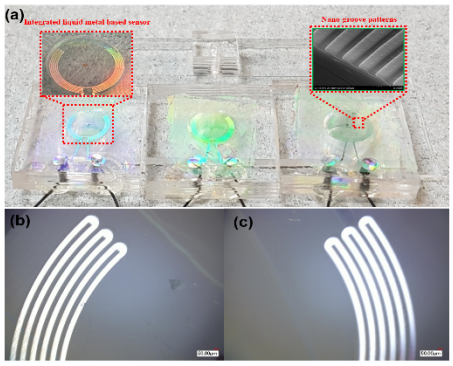

Fig.3 (a) Optical image of cell culturing platform with 3 individual liquid metal based sensor, (b & C) Microscopic image of liquid metal (Galinstan) in micro-channels

Mechanical stimulation

Mechanical Stimulation	
Frequency	1 Hz
Duty Cycle	50 %
Stimulation Type	Cyclic
Duration	7 days

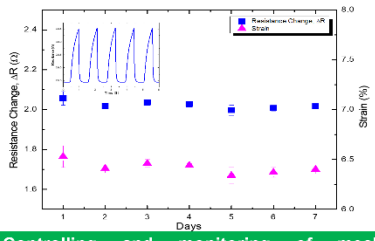

Fig.4 Controlling and monitoring of mechanical stimulation with integrated liquid metal based strain gauge and it exhibits excellent stability even after 7 days continuous stimulation

Sensor Characterization

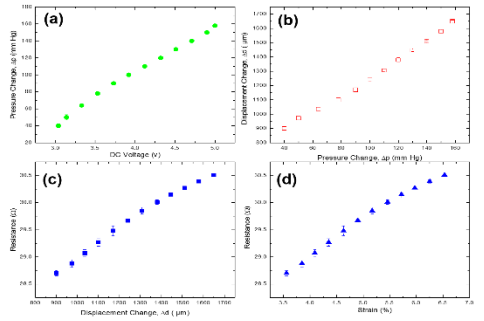

Fig.5 Characterization of liquid metal based sensor (a) Relationship between applied dc bias voltage and corresponding pressure change, (b) Relationship between pressure change and change in displacement, (c) Relationship between displacement change and corresponding change in resistance & (d) Relationship between strain and corresponding change in resistance

Result

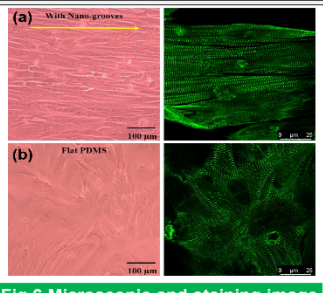

Fig.6 Microscopic and staining image of difference in cell alignment (a) on nano-groove and (b) on flat PDMS

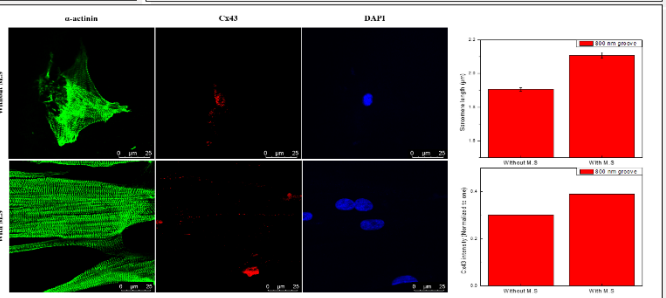

Fig.7 immunofluorescence staining data showing the different protein expression in the presence and absence of external (mechanical) stimulation

Conclusion

- ✓ A novel cell culture platform is introduced with integrated liquid metal strain gauge for monitoring and controlling of mechanical stimulation.
- ✓ The fabricated sensor shows excellent stability even after long term mechanical stimulation (7 days).
- ✓ Cells are observed to be aligned nicely in the nano-groove direction and there are clear differences between cells grown on the patterned surface and flat surface which is also proved by immunofluorescence staining.
- ✓ From staining, it is observed that sarcomere length and Cx43 intensity is increased in mechanically stimulated cells by 10% and 30% respectively compared to cells with -out any external stimulation.

Acknowledgements

✓ **This study was jointly supported by the National Research Foundation of Korea(NRF) grants funded by the Korea government(MSIT)(No.2017R1E1A1A01074550) & (MSIT)(No.2020R1A5A8018367).**