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한국정밀공학회
2015년도 춘계학술대회

- 일 자 : 2015년 5월 13일(수) ~ 5월 15일(금)
- 장 소 : 라마다프라자제주호텔
- 주 최 : 사단법인 한국정밀공학회
- 후 원 : 한국과학기술단체총연합회
  - Jeju 제주특별자치도
  - Jeju CVB Jeju Convention & Visitors Bureau |사|제주컨벤션뷰로

KSPE Korean Society for Precision Engineering

Korean Society for Precision Engineering

구두발표 / 5월 15일(금) 제7발표장

나노마이크로기술-3 ➡ 09:30 ~ 10:50		좌장 : 이문구(아주대학교)
176	09:30-09:50	스마트 스텐트 활용을 위한 무선 제어 형상 기억 합금 액츄에이터 *아웨스(전남대학교), 이동원(전남대학교), 박종성(전남대학교)
178	09:50-10:10	인공구조물을 이용한 파동에너지 제어 및 응용 *이학주(한국기계연구원), 김광섭(한국기계연구원), 김재현(한국기계연구원)
179	10:10-10:30	전기방사 기반의 나노제너레이터 제작 *장신(한양대학교), 오제훈(한양대학교), 김영준(한양대학교), 김현진(한양대학교)
181	10:30-10:50	마이크로채널 소자 제작을 위한 융착 및 패키징 실험 *우상원(한국기계연구원), 유영은(한국기계연구원), 정재성(한국기계연구원), 박시환(울산과학대학교), 김선경(서울과학기술대학교)

나노마이크로기술-5 ➡ 13:00 ~ 14:20		좌장 : 이봉기(전남대학교)
188	13:00-13:20	집광 빔을 이용한 박막 소자의 선택적 전사 *임형준(한국기계연구원), 이상욱(한국기계연구원), 김재구(한국기계연구원), 김재현(한국기계연구원), 김기홍(한국기계연구원), 최기봉(한국기계연구원), 이재종(한국기계연구원), 이성휘(한국기계연구원)
190	13:20-13:40	양극 산화 알루미늄 (AAO) 기반의 나노입자를 이용한 하이브리드 멤브레인 제작에 관한 연구 *NGUYEN THI PHUONG(한국기계연구원), 윤재성(한국기계연구원), 여은주(과학기술연합대학원대학), 안디(한국기계연구원), 김정환(한국기계연구원), 최두선(한국기계연구원), 유영은(한국기계연구원)
191	13:40-14:00	PDMS Roll 스탬프를 이용한 R2P 그라비아 인쇄의 고해상도 패터닝을 위한 공정연구 *최예찬(한국산업기술대학교), 김광(한국산업기술대학교), 이건훈(한국산업기술대학교), 문거성(한국산업기술대학교)
193	14:00-14:20	전해질 기반 전기방사를 이용한 3차원 표면 위 독립지지 나노파이버 멤브레인 제작 *박상민(포항공과대학교), 김동성(포항공과대학교)

스마트 스텐트 활용을 위한 무선 제어 형상 기억 합금 액츄에이터

Wirelessly Controlled Shape Memory Alloy Actuator for Smart Stent Application

***아웨스, 박종성 , #이동원**

*Awais Mahmood, Jongsung Park, #Dong-Weon Lee(mems@jnu.ac.kr)

MEMS and Nanotechnology Laboratory, Department of Mechanical Engineering, Chonnam National University, Gwangju, Republic of Korea

Key words : Shape Memory Alloy, L-C stent, Resonance, Wireless Actuation, Radio Frequency, Restenosis

1. INTRODUCTION

Coronary artery stents are used to reduce blockage in coronary arteries followed by an invasive procedure known as percutaneous transluminal coronary angioplasty (PTCA) [1]. Although angioplasty is an effective treatment for partially blocked blood vessels, but restenosis or re-narrowing of blood vessels affect 30-40% of patients within 6 months followed by PTCA treatment [2]. One solution to restrain thrombosis (restenosis) is moderate heating of stents, somewhat around 50°C is effective to curb thrombosis [3].

In this research project we intend to use shape memory alloy (SMA) due to its promising mechanical properties and capability to actuate wirelessly. A helical structured inductive stent is laser cut from Nitinol tube. The stent is then electromechanically coupled with parallel plate capacitor build by MEMS process to obtain an L-C resonant stent. This stent can be operated by external RF source to actuate wirelessly and heat for endohyperthermia treatment by utilizing joules heating phenomenon in order to inhibit in-stent restenosis.

2. DESIGN AND FABRICATION

The stent structure is produced by laser micromachining medical grade nitinol tube (4.5mm outer diameter, 100㎛ wall thickness). This stent would work as a mechanical scaffold and an L-C tank circuit. Commercial stents normally have connection struts between the loops which cause electrical shortening and resulting in low inductance. A helical stent without having connection struts between the loops provides a stent of high inductance which aid to have an efficient L-C tank circuit. The helical stent contains 18 loops having 9 zigzag patterns in each loop. The length of stent is 25mm with strut thickness of 335㎛; these dimensions are chosen to have maximum inductance value. The capacitor strips are built by MEMS process with an overlap area of $1mm^2$ and separation distance between the plates is 10㎛. Both capacitor and inductor (stent) are bonded together by using conductive silver epoxy to obtain an L-C resonant circuit.

3. EXPERIMENT AND RESULT

The inductance and capacitance of L-C stent is measured by using RLC meter which is found to be around 400nH and 25pF respectively. Resonance frequency of electromechanically coupled L-C stent is examined by using Aglient 4395A Network analyzer, which is 53.95 MHz. The measured resonance frequency matches well with the theoretical value, which is 50.3 MHz. The resonance peak of stent is shown in figure 3.

To ensure the reliability of fabricated device (stent), helical stent is coupled with commercial capacitor having 20pF capacitance and the resonance peak is examined as shown in figure 4. The results show that the helical stent has definite inductance and it is working properly, by incorporating it with different capacitor we can obtain different resonance frequency depending on the capacitance of the device used. The experimental results related to actuation of stent would be presented at the conference.

4. CONCLUSION

In this paper we have presented the design, fabrication and resonance measurement of L-C resonant stent which can be heated by utilizing joules heating phenomenon. This design of stent would be able to actuate wirelessly and can be used for endohyperthermia treatment for in-stent restenosis.

ACKNOWLEDGEMENT

This study was supported by a grant of the Korean Health Technology R&D Project (HI13C1527) Ministry of Health & Welfare, Republic of Korea and International Collaborative R&D Program through KIAT grant funded by the MOTIE (N0000894).

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2. Rajagopal, Vivek, and Stanley G. Rockson. "Coronary restenosis: a review of mechanisms and management." The American journal of medicine 115.7 (2003): 547-553.
3. Brasselet, C., Durand, E., Addad, F., Vitry, F., Chatellier, G., Demerens, C., & Lafont, A. "Effect of local heating on restenosis and in-stent neointimal hyperplasia in the atherosclerotic rabbit model: a dose-ranging study." European heart journal (2008).

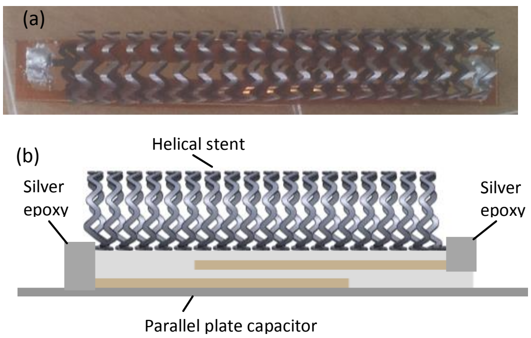


Fig. 1 (a) shows the real L-C stent and (b) shows the schematics of L-C stent

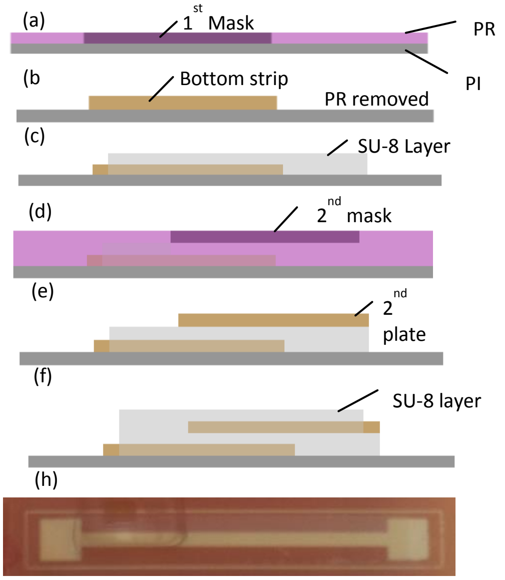


Fig. 2 Process flow schematics of parallel plate capacitor (h) real device.

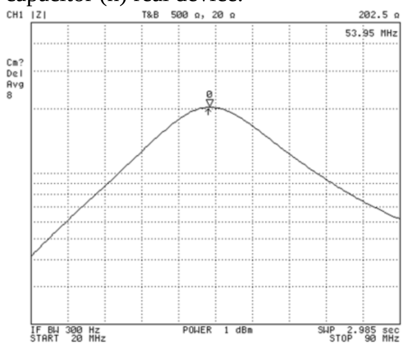


Fig. 3 Resonance frequency of L-C stent with MEMS capacitor, 53.95MHz

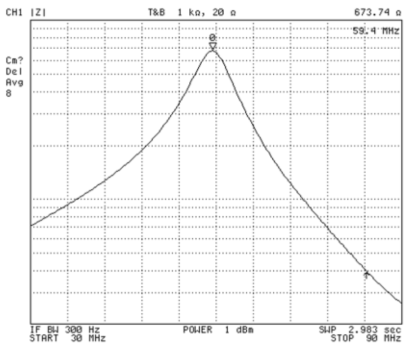


Fig. 4 Resonance frequency of L-C stent with 20pF commercial capacitor, 59.4MHz

Wirelessly Controlled Shape Memory Alloy Actuator for Smart Stent Application

스마트 스텐트 활용을 위한 무선 제어 형상 기억 합금 액츄에이터

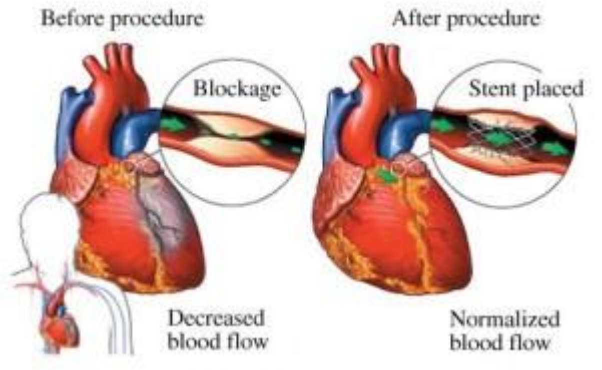
Awais Mahmood
(PhD Student)

Outline

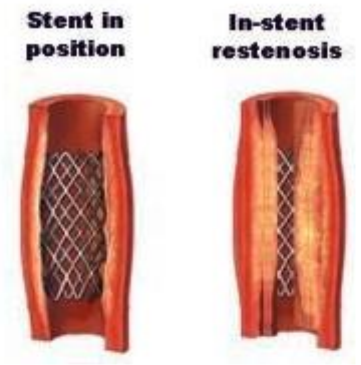
- Introduction
- Research Plan
- Current Progress
- Conclusion/Future Work

INTRODUCTION

- Each year, three million stents are implanted worldwide, for both vascular (e.g., coronary, carotid, renal, and peripheral arteries) and non-vascular (e.g., urinary and biliary ducts) applications.
- Stents are most widely used for cardiovascular disease, the number one cause of death in North America.
- Restenosis (re-narrowing of blood vessels) occurs in stented patients with substantial rates e.g., up to 30%, mainly due to scar-tissue proliferation within the stent. When severe, it may lead to complete blockage of blood flow.



Stent implant by angioplasty (PTCA)



Restenosis occurs inside implanted stent

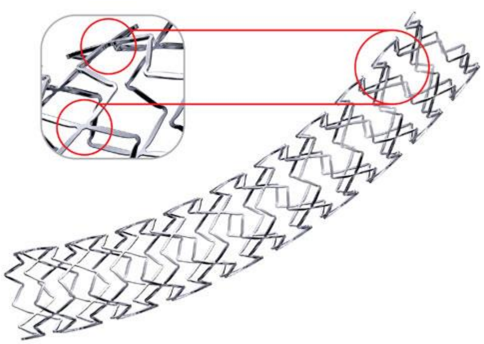
Continued

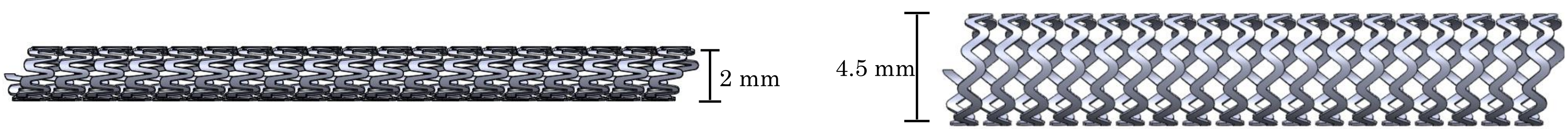
- In order to restrain restenosis number of different kinds of solutions have been proposed.
- Drug Eluting Stent (DES). But this method is not helpful in long term application and in most of cases restenosis occur after 6 months of stent implant.
- Using Bio-absorbable stent, uncontrolled degradation rate of stent still needs to be addressed.
- Hyperthermia treatment (at temperature ~50 °C) of stent could be effective in limiting cell proliferation (restenosis).

Research Plan

- A helical type stent is designed in order to obtain a stent with inductor characteristics.
- By removing connecting struts between the loops, inductance of the stent can be greatly increased.
- This stent will act as a mechanical scaffold and an active antenna for RF power transfer.
- Inductive stent can be electromechanically coupled with capacitor to obtain an L-C resonant stent.

Commercial stent having connection struts





3D image of helical stent having no connection struts between the loops, before and after expansion

Continued

- Development of smart shape memory alloy (SMA) stent for hyperthermia treatment and wireless actuation.
- RF power can be used to heat resonant stent.
- SMA can be actuated by using Joules heating phenomenon.

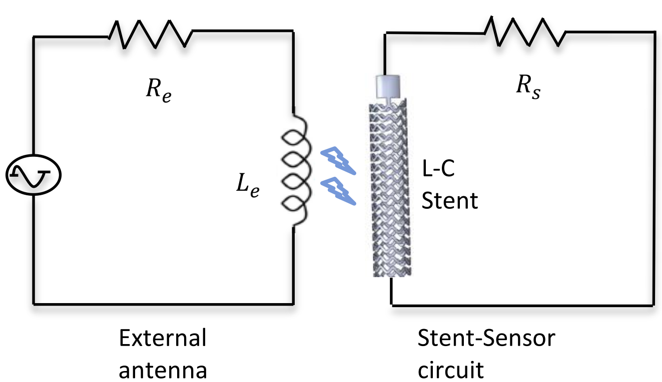


Figure 2: Equivalent circuit of L-C stent

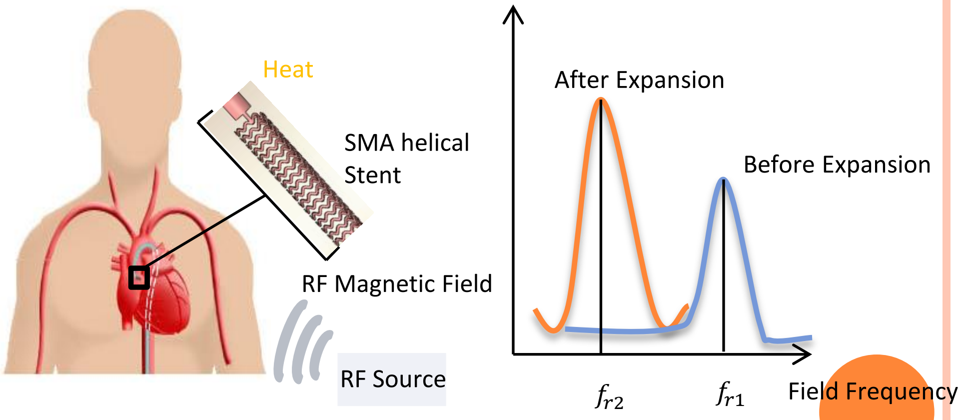
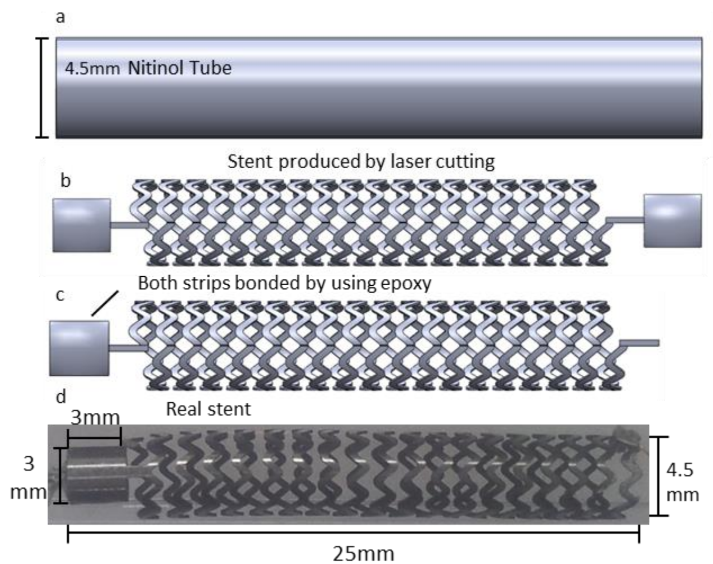


Figure 1: Conceptual illustration of L-C stent

Current progress

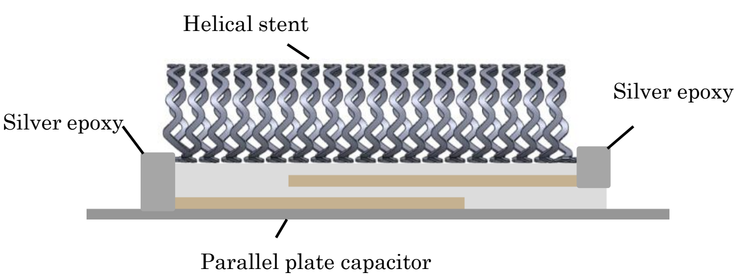
- L-C stent development using Nitinol tubes.
- Helical type stent is designed and laser cut from 4.5 mm Nitinol tubes.
- Capacitor part is build by bonding two strips using a non-conductive epoxy in between.



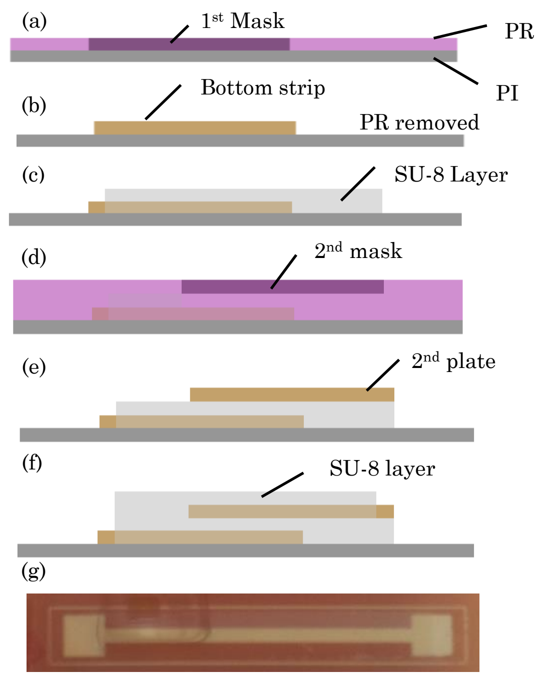
Schematic diagram of stent fabrication (a) 4.5 mm medical grade Nitinol tube (b) stent produced by laser cutting (c) plates are bonded together by using non-conductive epoxy (d) real L-C stent

Continued

- Designing and fabrication of parallel plate MEMS capacitor.
- Helical stent is bonded with capacitor by using silver epoxy.
- Capacitance is found to be around 25pF.



Top real L-C stent and bottom is the schematic of L-C stent



(a-f) Process flow schematics of parallel plate capacitor (g) real device.

CONTINUED

- To validate the results helical stent is coupled with commercial capacitor.
- A 20 pF commercial capacitor is electromechanically coupled with helical stent and its resonance frequency is analyzed.

Capacitor

Resonance Frequency Measurement

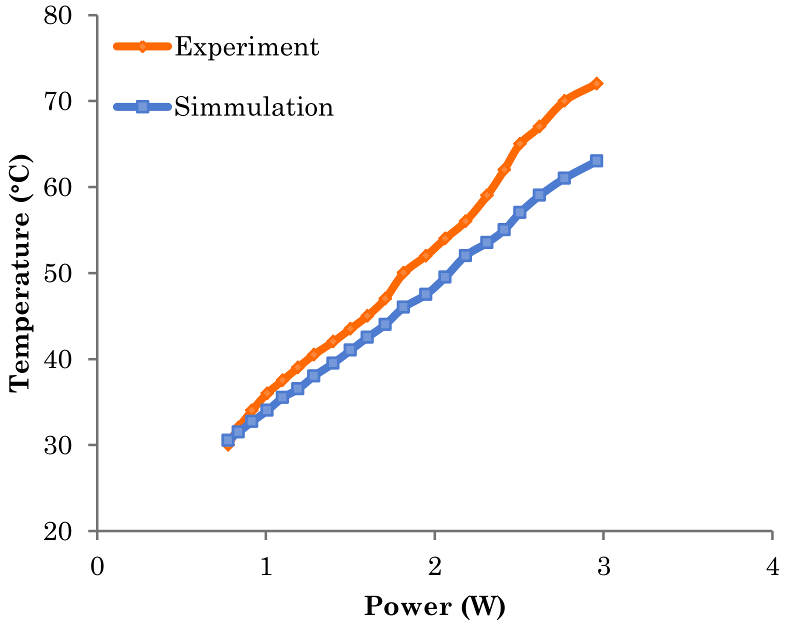
- Resonance frequency of three different types of L-C stents is measured by using Agilent 4395A network analyzer.

Type of Stent	Sample # 1	Sample # 2
Stent with commercial capacitor	C=30pF f_r=50.15MHz	C=20pF f_r=62.5MHz
Stent with laser cut parallel plate capacitor	C=3.1pF f_r =110.0MHz	C=3.1pF f_r =134.5MHz
Stent with MEMS capacitor	C=25pF f_r=52.32MHz	C=25pF f_r=72.5MHz

Resonance frequency measurement of L-C stent having three different types of capacitors with same type stent having inductance in range of 375-425nH

Joules Heating

- To analyze joules heating effect on the stent structure, DC power is applied across the stent.
- The results of both experiment and simulation are shown bellow.



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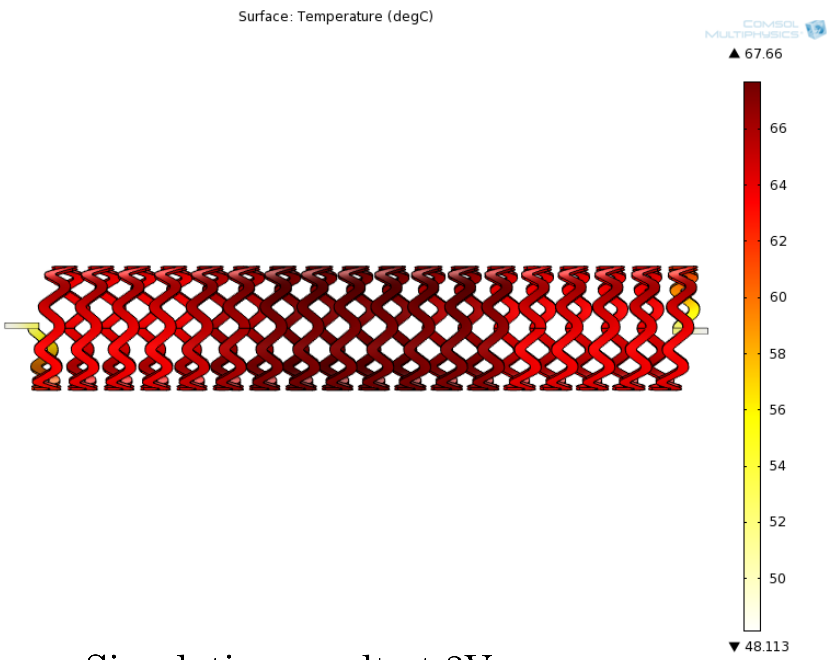
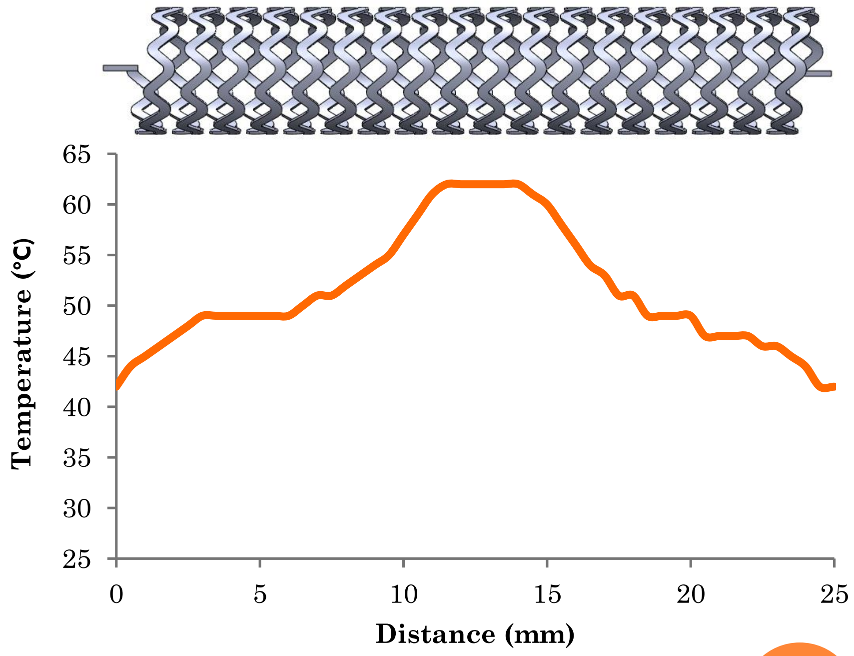
- Temperature distribution on stent surface, experimental and simulation results at 3V.



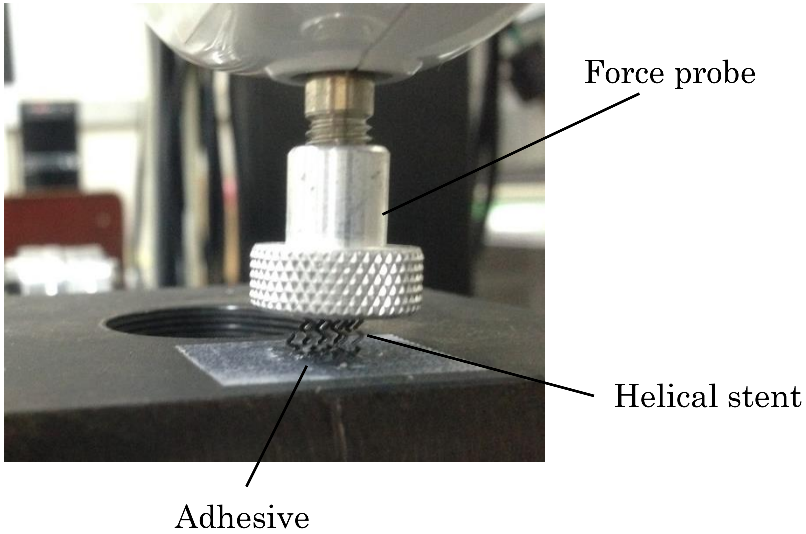
Simulation result at 3V

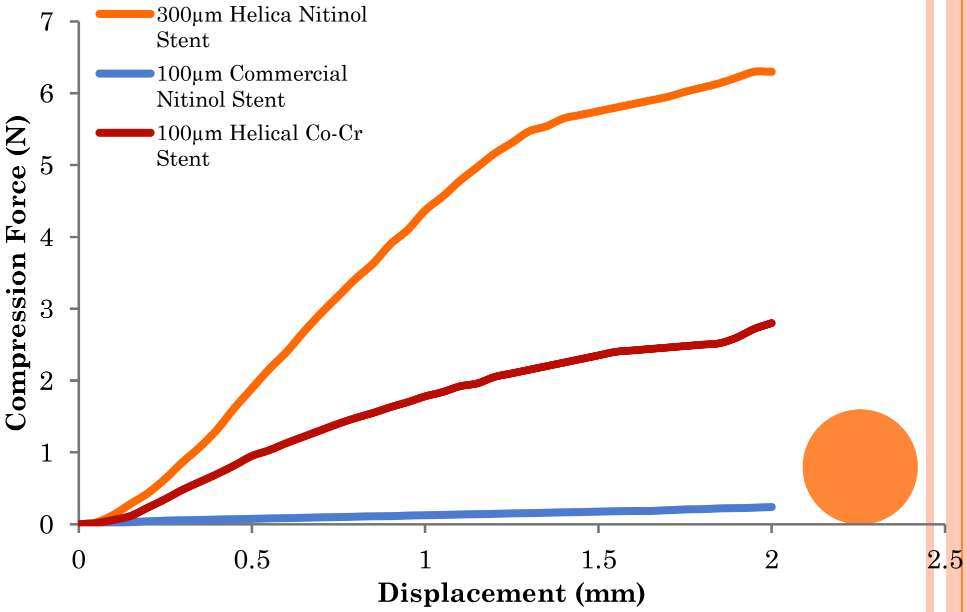


Experiment result at 3V

Mechanical Characteristics

- In order to confirm the mechanical integrity of stent, compression force analysis is done on helical stent in comparison with commercial stent.
- Stent should be designed to withstand the internal wall pressure of the coronary artery.
- Due to thicker strut thickness, SMA helical stent withstand maximum force of up to 6N.





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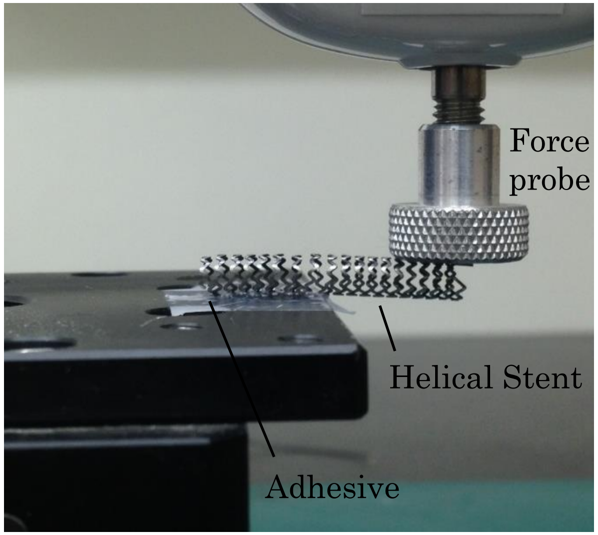
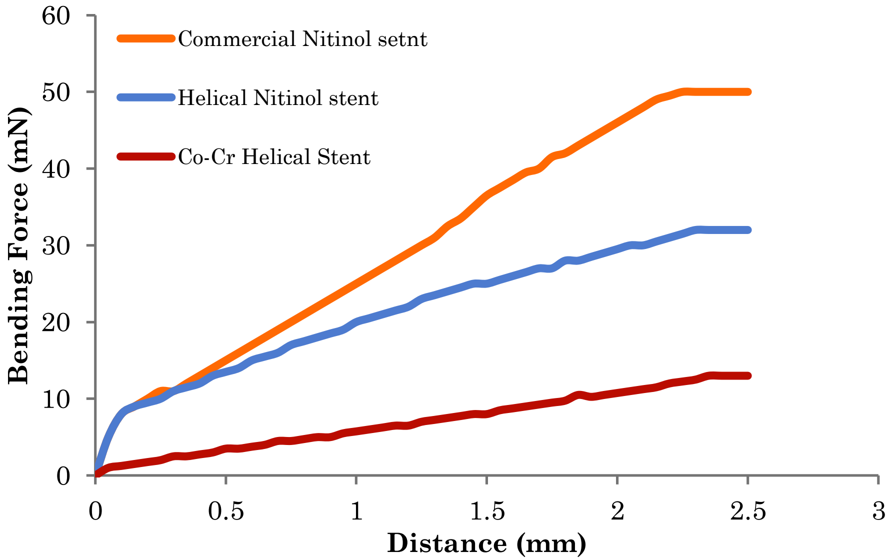
- To adapt the environment of the artery, stent should be flexible enough.
- Bending force analysis.





Conclusion

- Helical stent is successfully designed, fabricated, and electromechanically coupled with capacitor to obtain an L-C resonant stent.
- Stent shows good electrical properties in order to operate under external RF source.
- Stent shows good mechanical properties in comparison with commercial stent and can be used for practical application.

Future work

- Designed L-C stent would be operated by utilizing RF power for wireless heating and actuation both in vivo and vitro.
- Design characterization would be done to have a more uniform temperature distribution along the stent surface.

Thank you for listening!

This study was supported by Korean Health Technology R&D Project (HI13C1527) Ministry of Health & Welfare, Republic of Korea and International Collaborative R&D Program through KIAT grant funded by the MOTIE (N0000894).