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Smart Sensors Lab
Ideas, Innovation, Impact

An optimized methodology to achieve irreversible bonding between PDMS and polyimides for biomedical sensors

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Outline

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Problem Statement

- Conductive patterns and flexible substrates are the key components of sensors [1]
- Polydimethylsiloxane (PDMS) is the most popular substrate due to its flexibility, compressibility and biocompatibility [2]
  - Hydrophobic nature of PDMS: Weak adhesion between PDMS and conductive patterns [3]

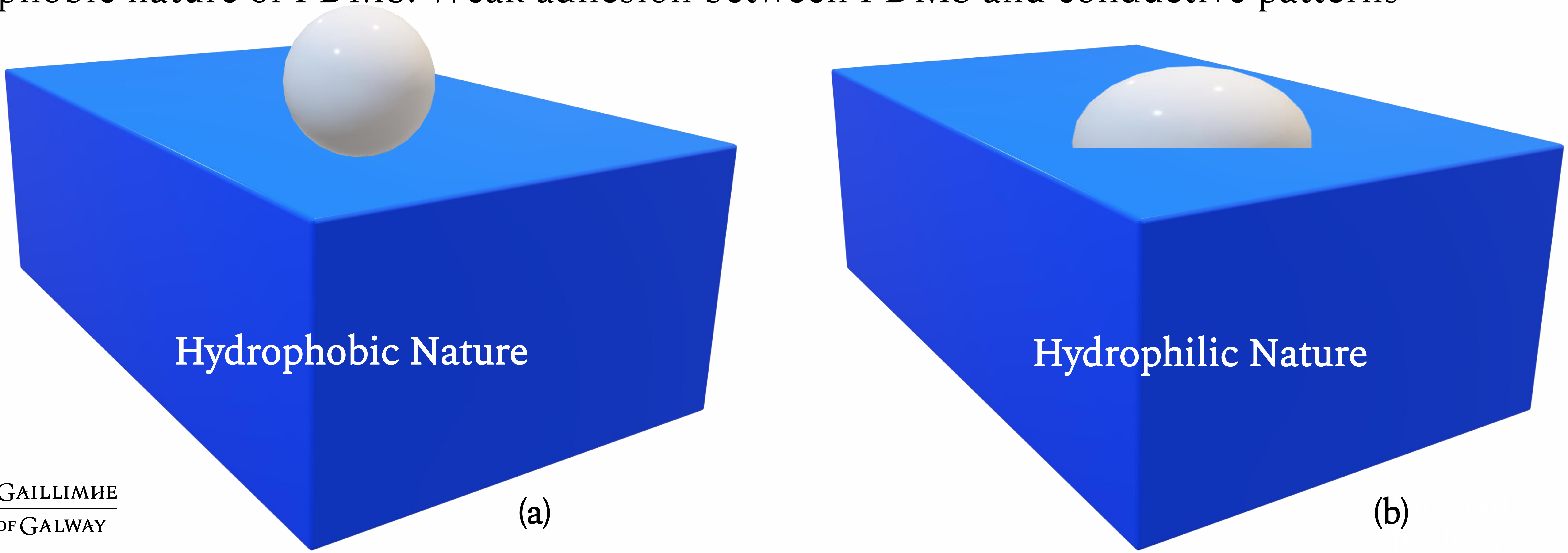

Figure 1: (a) Hydrophobic Nature (b) Hydrophilic Nature

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Proposed Approach

- Use additional substrate (Polyimide) between PDMS and conductive patterns
  - Polyimides are widely used for flexible electronics [4]
- Epoxy-thiol click chemistry: A sequential process to activate the surfaces of PDMS and Polyimide to achieve irreversible bonding
- To demonstrate the optimized fabrication process a wireless pressure sensor is reported [5]

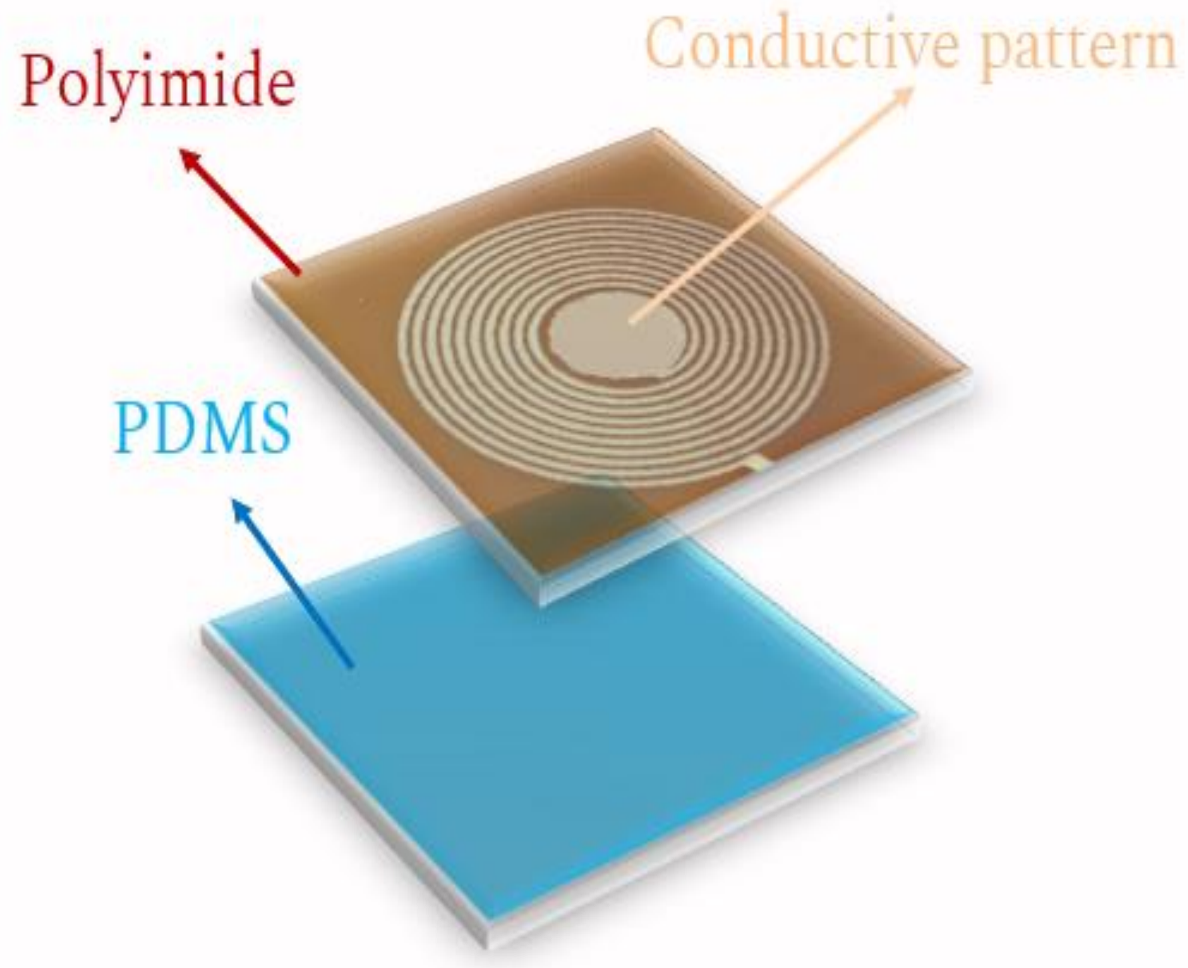

Figure 2: Proposed solution representing Polyimide as intermediate layer between PDMS and conductive traces

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Sensor Design and Pattern Development

a) Circular LC pressure sensor
- solid disk represents the capacitor (C)
- spiral traces represent the inductance (L)

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

b) Mask printing on copper-coated polyimide sheets (**LaserJet printer**)
c) Wet etching inside the bubble etching tank (**Sodium per sulphate at** $45^{o}C$)
d) Removal of ink and residual etchant (**Acetone and deionized water**)

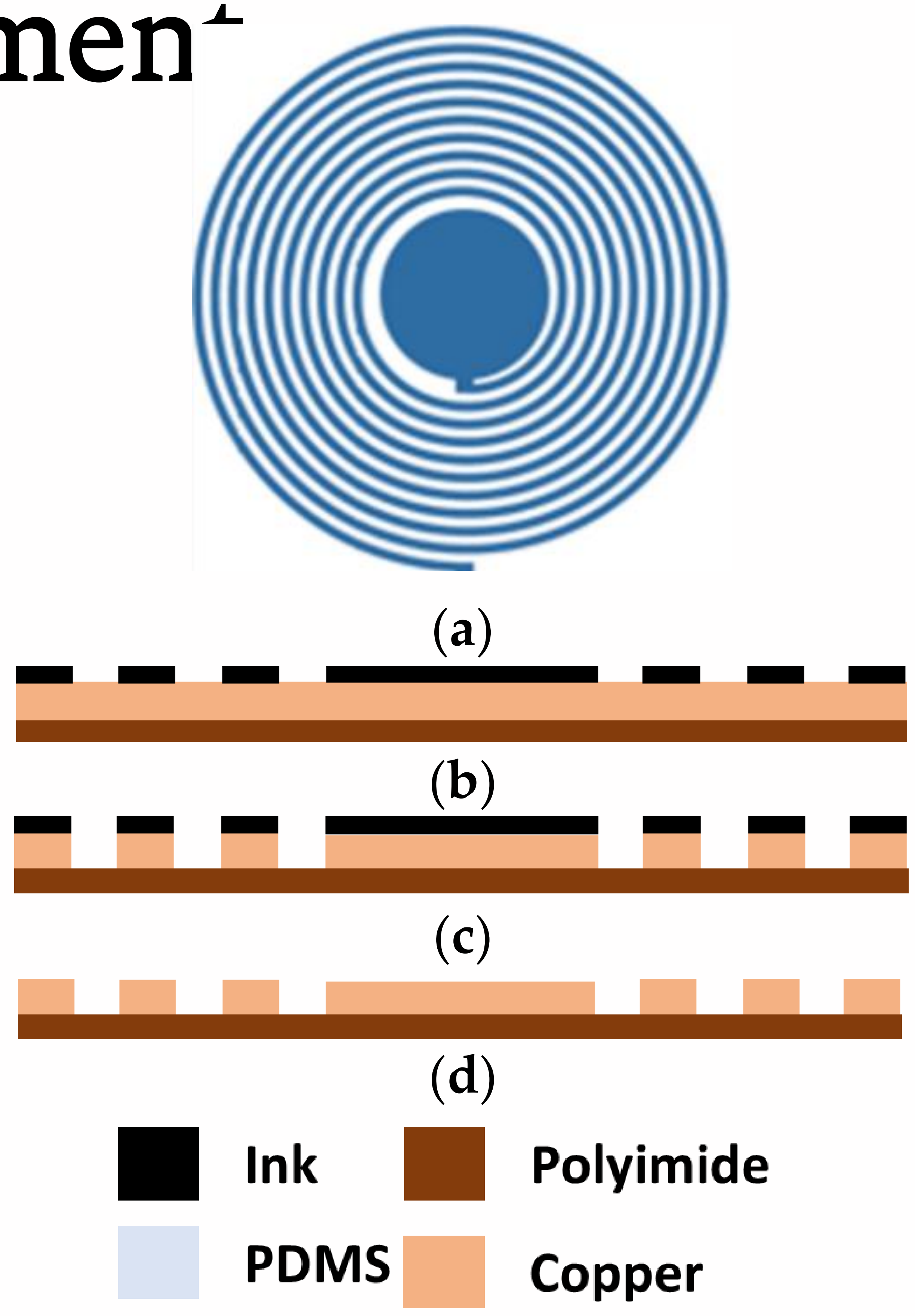

Figure 3: (a) Sensor design (b) Ink mask printed (c) Sensor patterns (d) Sensor patterns after cleaning

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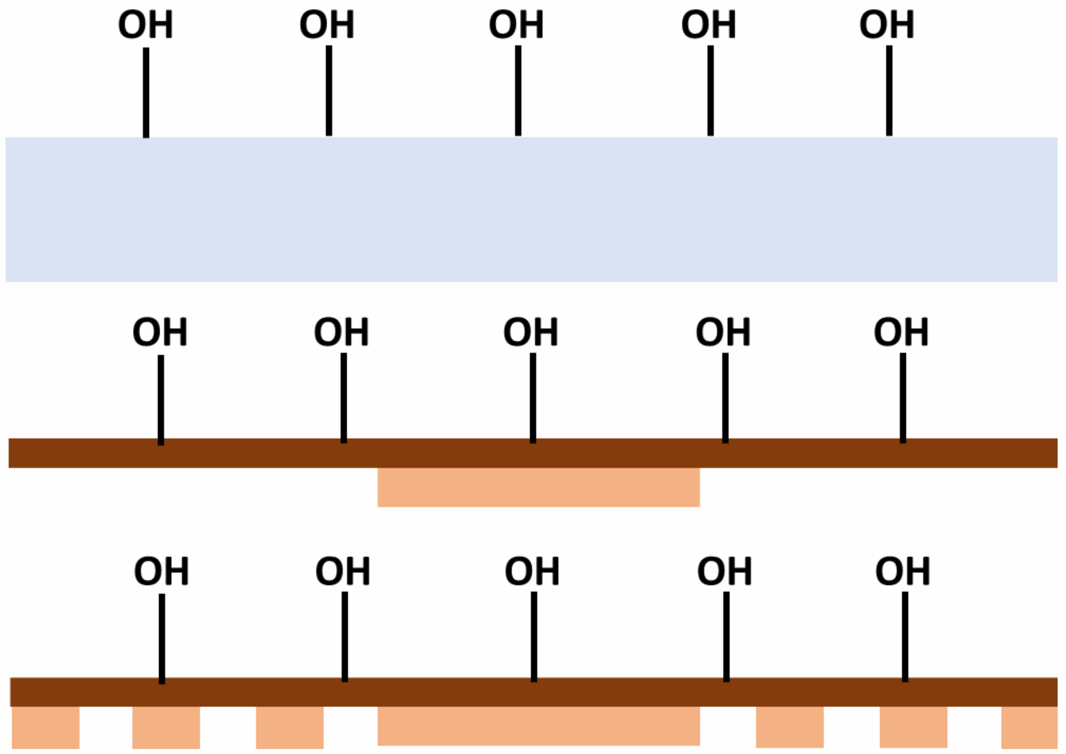
Plasma Treatment and Surface Functionalization

e) Hydroxylation on the surface of PDMS and patterned polyimide sheet

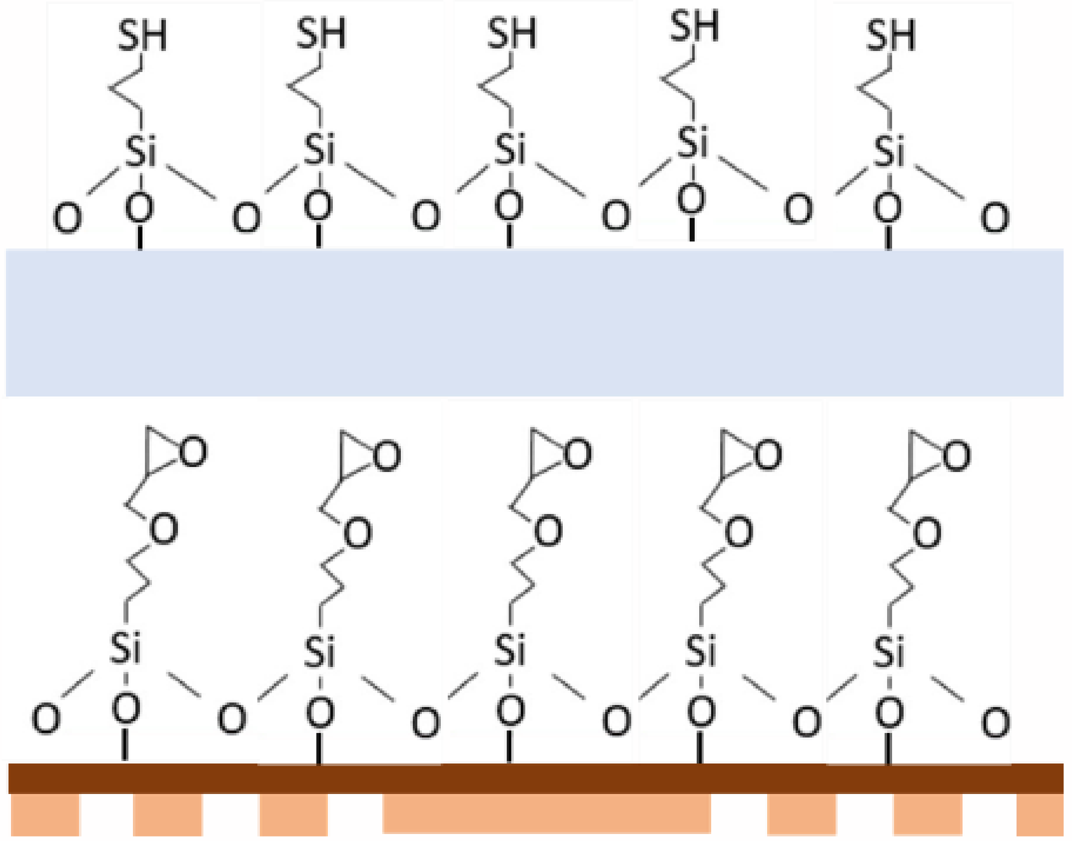
- Glass chamber of the plasma oven was pressurized to a 100-130 $mTorr$
- RF level was set to high for 45 Sec

f) Surface functionalization

- 1% v/v and 2% v/v solution of (3-mercaptopropyl) trimethoxysilane (MPTMS) and (3-glycidyloxypropyl) trimethoxysilane (GPTMS) in methanol under nitrogen environment were prepared
- Plasma-treated PDMS was immersed in MPTMS for 1 hr
- Plasma-treated patterned polyimide was immersed in GPTMS for 1 hr



(e)



(f)

Figure 3: **(e)** Plasma treatment of PDMS and polyimide **(f)** Chemical surface functionalization

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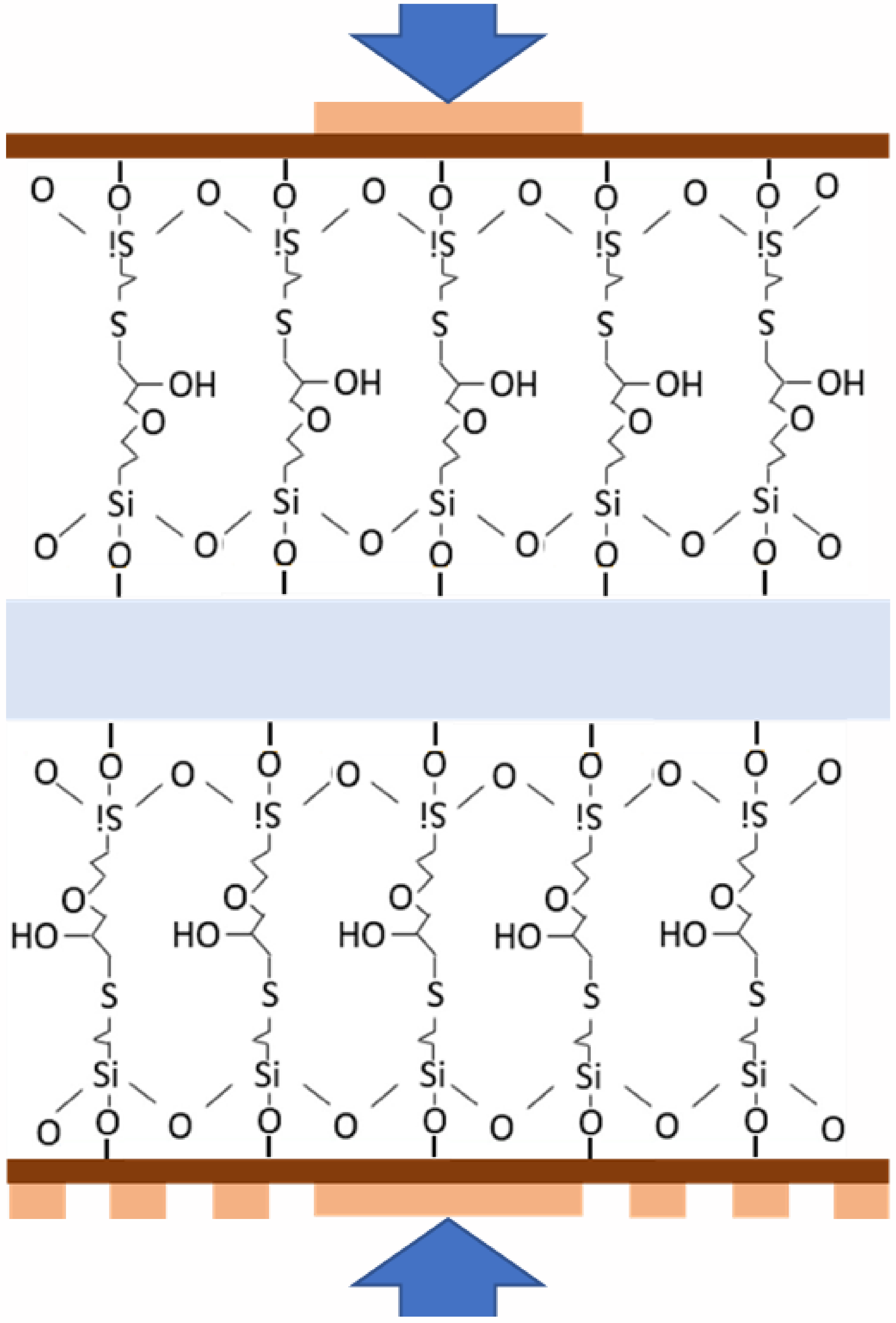
Final Assembling of the Sensor

g) Chemically functionalized PDMS was sandwiched between sensor-patterned polyimide

- Under 10-15 kPa pressure for 24 hrs



(g)

Figure 3: **(g)** PDMS sandwiched between polyimide sheets under pressure

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Results

- A peel-off test was used to check the bonding strength
  - Adhesive failure (surficial bonding between the two different layers of materials fails)
  - Cohesive failure (when one of the bonded materials tear-off instead of surficial bonding failure)

(a) (b)

Figure 4: (a) Adhesive Failure for 1% v/v solutions
(b) Cohesive Failure for 2% v/v solutions

Fatigue Testing

- Sensor was placed inside an acrylic pressure chamber
  - Cyclic pressure between 45-95 mmHg for 1 million cycles
  - A cohesive failure was observed after 1 million loading and loading cycles

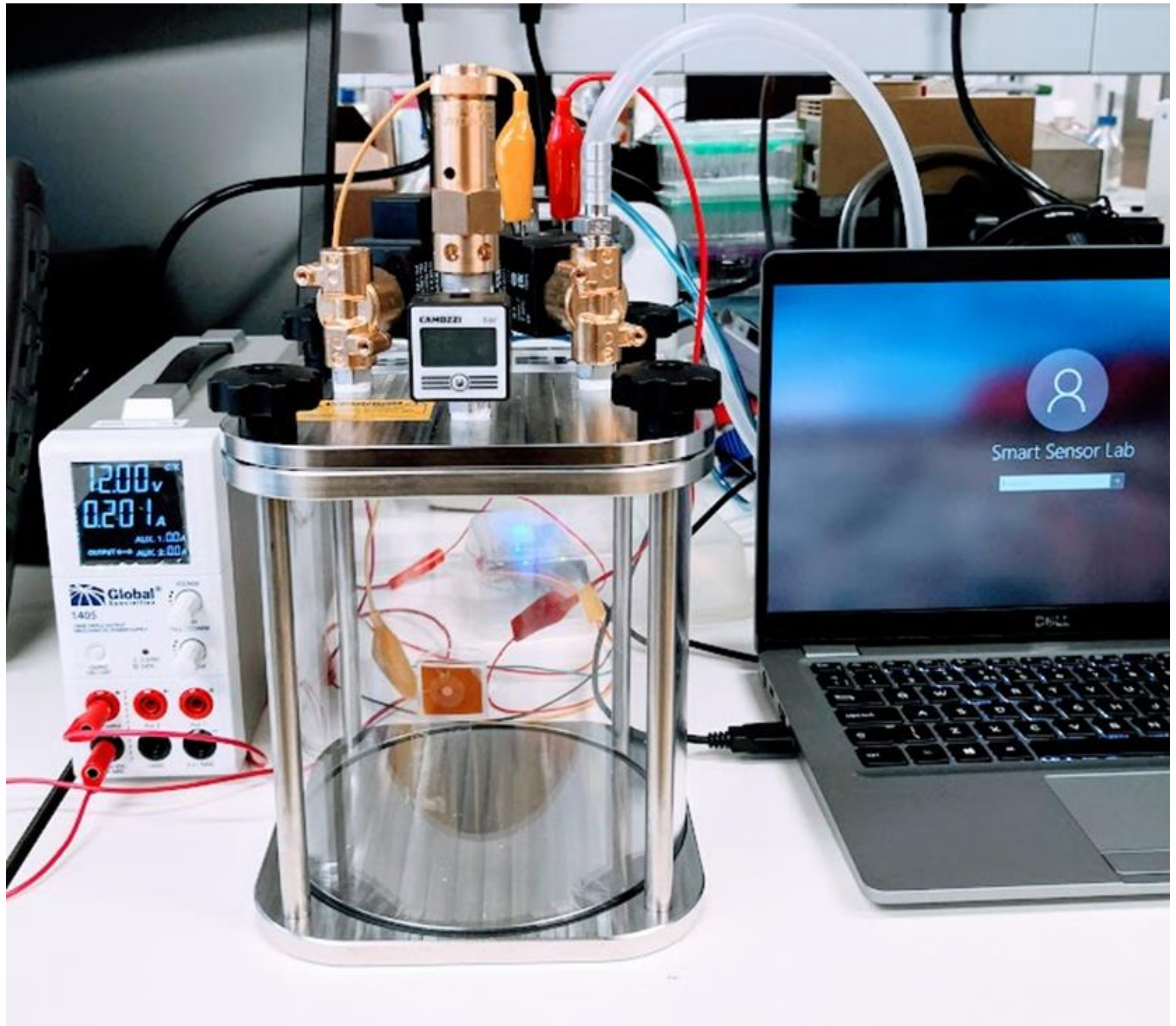

Figure 5: Fatigue test setup

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Conclusions

- This study has presented an efficient and cost-effective methodology to achieve an irreversible bonding
- Epoxy-thiol click chemistry is used to functionalize the Polyimide and PDMS surfaces to achieve an irreversible bonding
- The bonding did not fail over the sensor's 1,000,000 cycles of pressure testing
- The proposed approach indicates that the sensor's integrity, dependability, and stability had all improved

References

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[3] M. V Hoang, H.-J. Chung, and A. L. Elias, “Irreversible bonding of polyimide and polydimethylsiloxane (PDMS) based on a thiol-epoxy click reaction,” *J. Micromechanics Microengineering*, vol. 26, no. 10, p. 105019, 2016.

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Thank *you*

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