Development and Verification of Wet Testing Platform for BioMEMS Chips

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Shanghai ▪ October 31, 2024

Outline

- Introduction
- Establish testing platform
- Experience Result
- Conclusion and discussion

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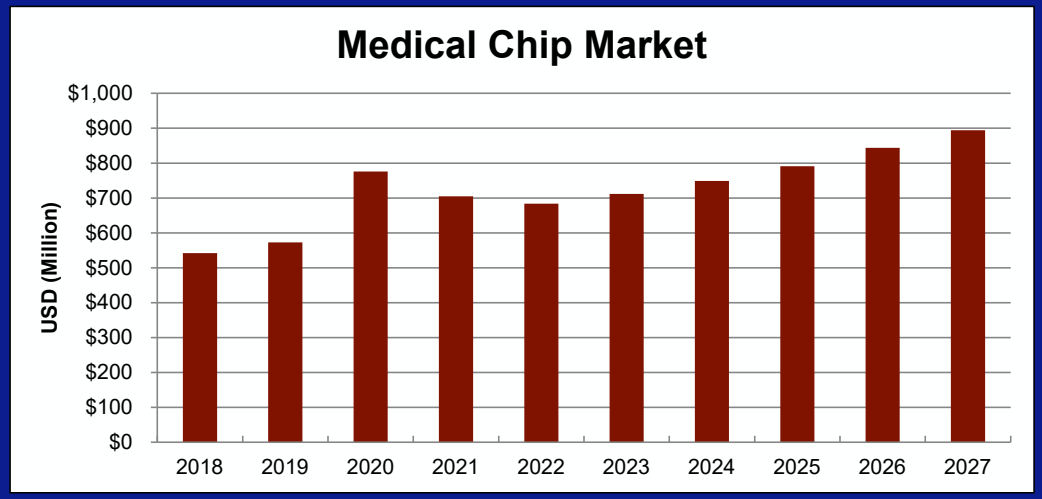
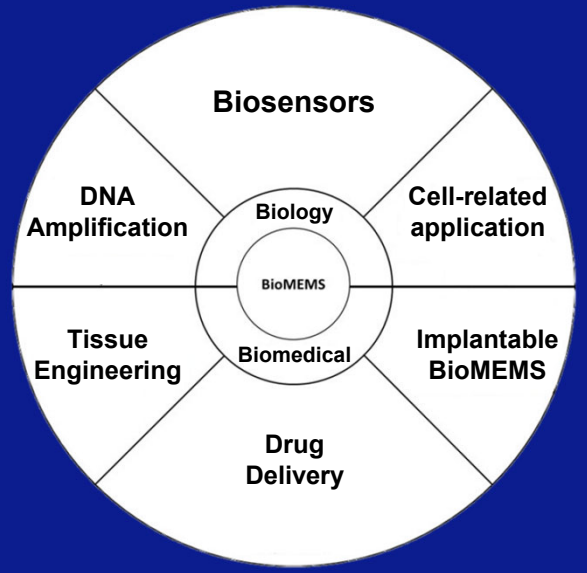
BioMEMS introduction

- BioMEMS is a rapidly developing field and BioMEMS can be applied to a wide area.
- After the outbreak of COVID-19, many medical companies have invested in the development of new types of BioMEMS.



BioMEMS introduction

- MEMS technology can reduce the size of Biomedical chips. The testing requires only a small amount of sample, reagent, and testing.
- Various companies are actively engaged in the fields of cancer detection, drug testing, home care (point of care) and rapid DNA sequencing.



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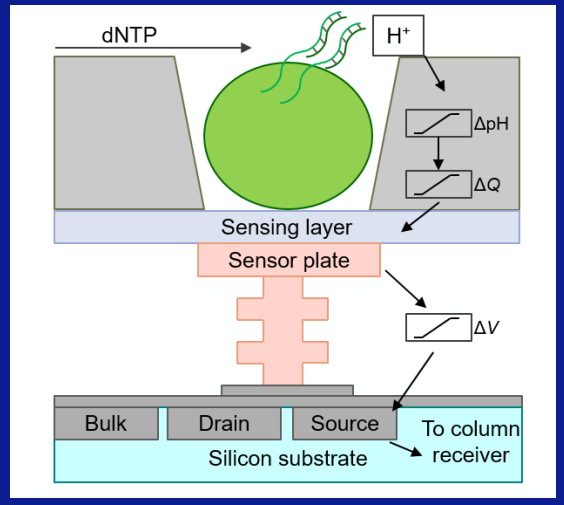
BioMEMS in DNA sequence

- DNA sequencing is a key application of BioMEMS, where MEMS devices with biological sensing layers allow for rapid gene detection.
- BioMEMS-based DNA sequencing provides fast, accurate, and cost-effective gene analysis, that can be widely used in cancer risk assessment, prenatal screening, and pathogen detection.



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Testing for BioMEMS

- Most biomedical chips operate in an aqueous environment, while conventional semiconductor testing measures electrical signals in dry conditions.
- The lack of advanced mass production testing technologies limits BioMEMS production capacity due to low testing coverage.
- Testing in liquid environments introduces challenges such as evaporation, incomplete coverage, and cleaning residue, which can affect measurement accuracy.

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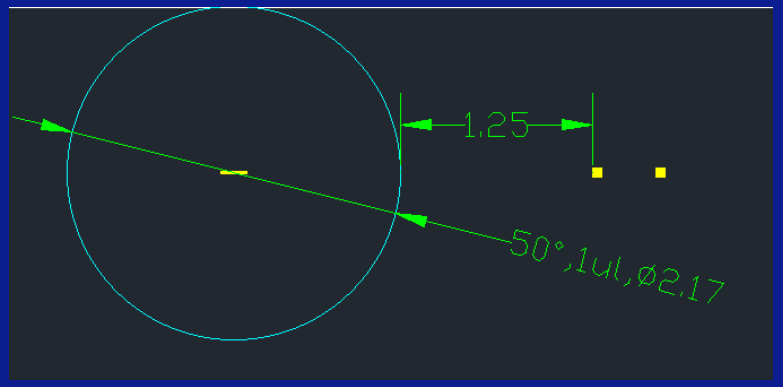
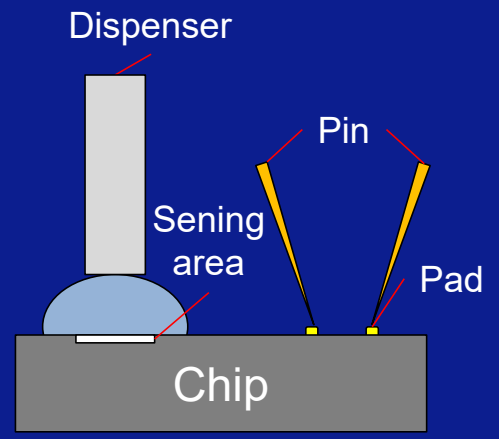
Wet testing process protocol

- 2 pads and 1 sensing area in each test key and 5 test key on each die.
- During wet testing, it is necessary to dispense the test solution onto the sensing area and probe on the pad.
- When 1 μl droplet was dispensed at the center of the array, the distance between the droplet and the pad is only 1.25mm.



Droplet diameter simulated



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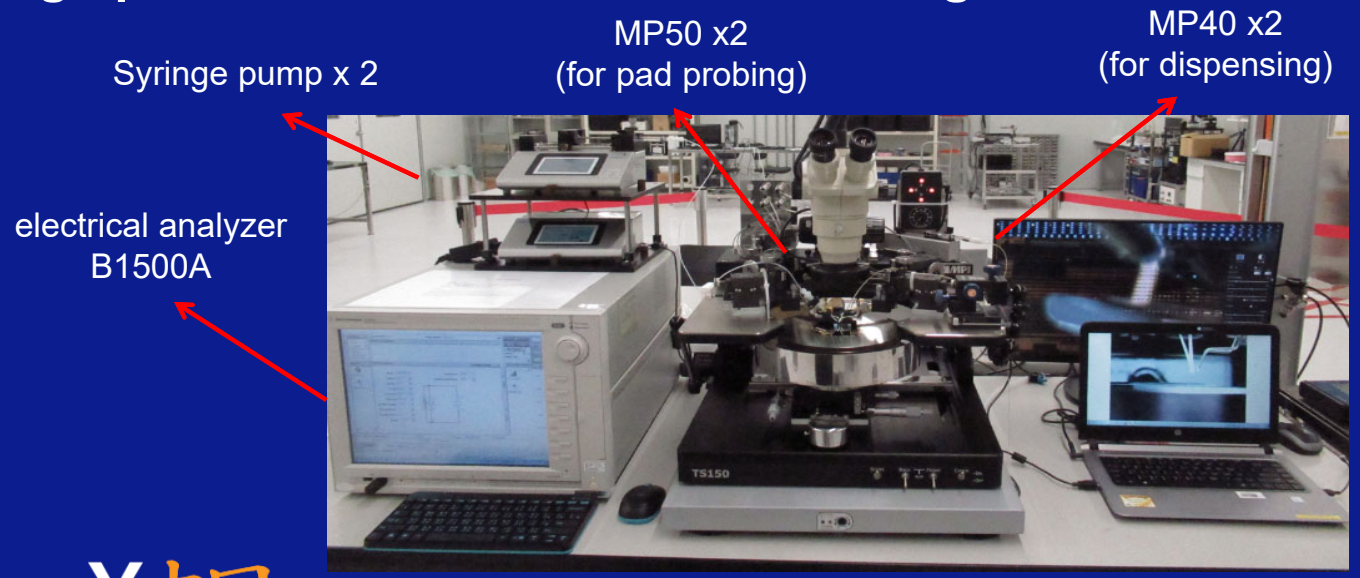
Wet testing process protocol

- The test platform is integrated with probe station, semiconductor electrical analyzer, and microfluidic control system.
- 2 micropositioners with Kelvin pins and 2 micropositioners with dispensing tip were added on TS150 for wet ting.



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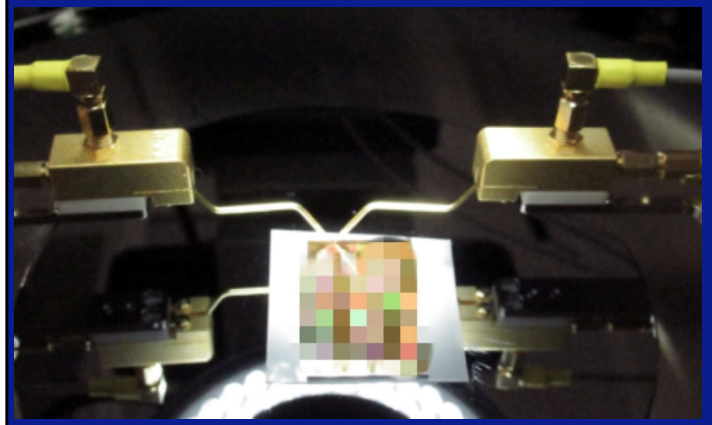
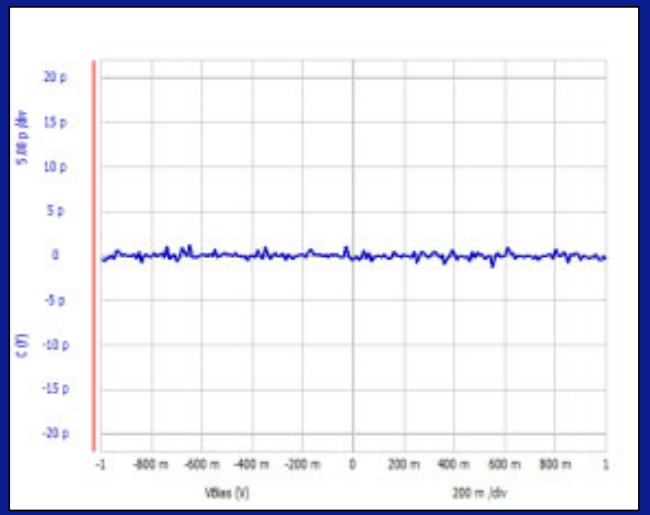
Capacitance testing system setting

- The semiconductor analyzer B1500A selected the capacitance-to-time (C-t) mode for measurement.





Parameter	
B1500A C-t Measure	
Voltage range	1 V
Interval	500ms
Frequency	1k Hz
Total sample data	7201
Test time	1 hr
Pump	
Flow rate (ul/min)	0.5
Test solution volume (ul)	1
Clean solution volume (ul)	1

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Wet testing process establish

Chip and position

- BioMEMS Chip Set Up
- Vacuum Chunk Hold Bare Chip
- Micropositioner set up
- Kelvin pin set up
- Dispensing tip docking

Dispense solution and wet testing

- Dispense NaCl(aq) to sensing area
- Kelvin pin contact to pads
- B1500A C-t testing
- Kelvin pin leave
- Vacuum up NaCl(aq) and clean chip

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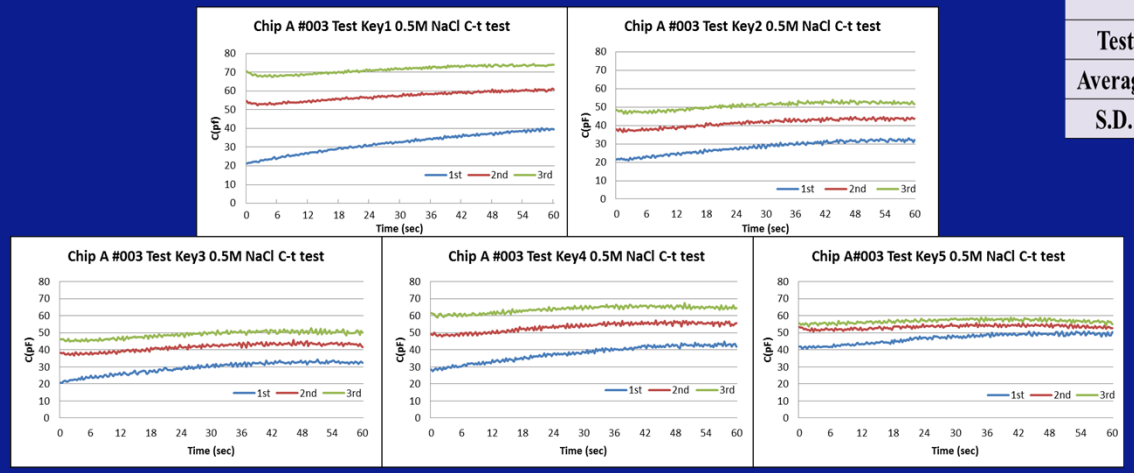
Short-term C-t result and characteristic verification

- Capacitance value increased continuously within one measurement.
- The initial and average capacitance values were higher and higher when more experiments was conducted.
  - The reaction time is an important factor in this chip.



Chip A #003 Test Key 0.5M NaCl C-t Test Summary					
Test Key	1	2	3	4	5
Average (pF)	53.59	40.09	39.89	51.56	52.29
S.D. (pF)	3.24	2.56	2.61	3.06	1.67

C-t test	
Vbase (V)	± 1
OscLevel (mV)	50
Frequency (Hz)	1K
Total sample data	121
Test time (Sec)	60

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Preliminary long-term characteristic verification

- Conducted long-term examination to further analyze chip characteristic.
- As the testing solution used should be less than 1 μl, it evaporates easily.
  - Keep replenishing the test solution when evaporation happens:
    1. Replenish DI H_2O, concentration of test solution will keep it in 1M.
    2. Replenish 1M NaCl, concentration of test solution will increase.

Examination process

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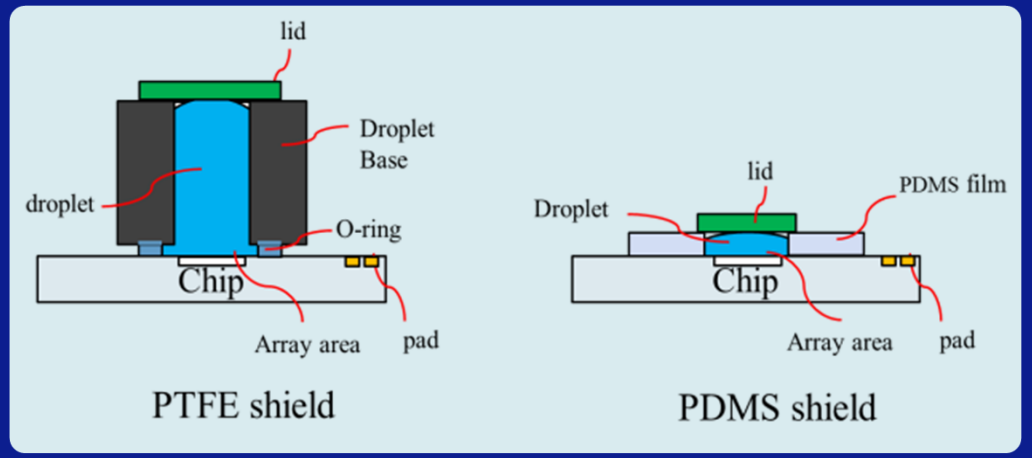
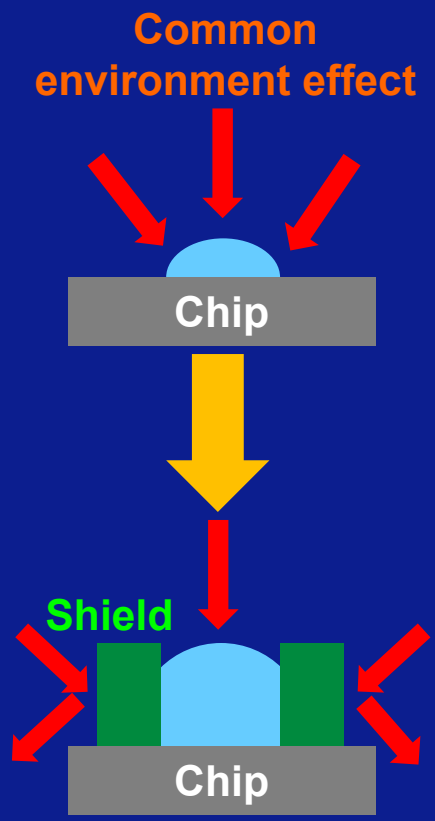
Water-retaining shield method

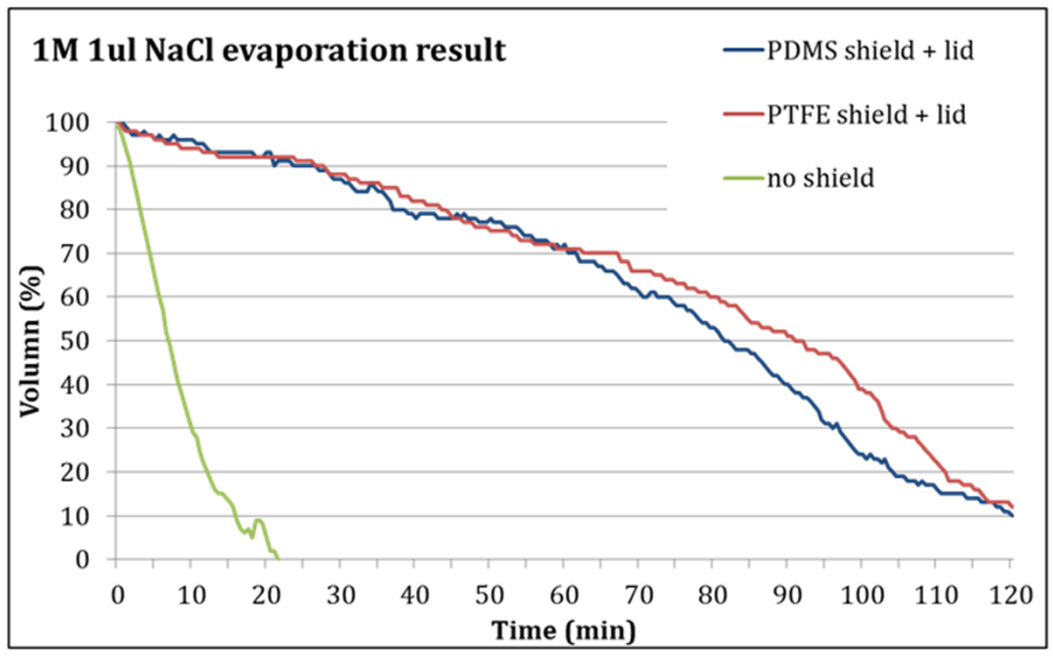
- Water-retaining shield method can prevent the test solution from contacting the pad.
- Shield can isolate the test solution from the environment and increase the volume of the testing solution.

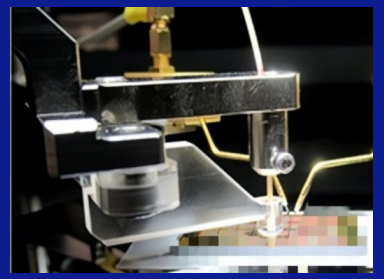




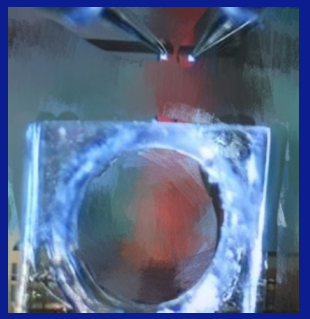
Water-retaining shield method

- Shield method can effectively reduce the solution evaporation rate.
- 1ul NaCl still remains at 10% volume after 2hr in shield method.





PTFE shield



PDMS shield

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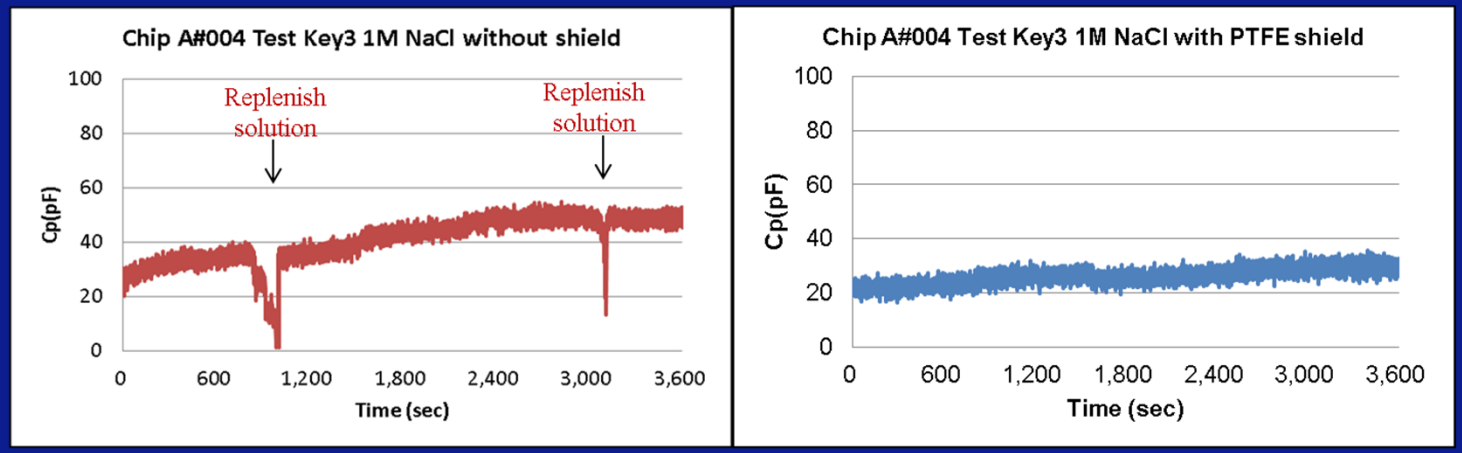
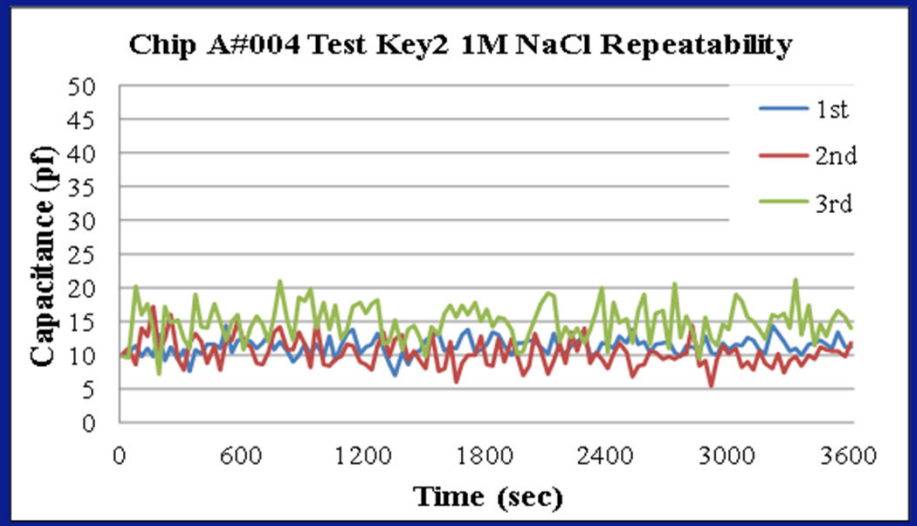
Water-retaining shield method

- In shield group, capacitance value increased from 20 pF to 30 pF.
- In control group, capacitance value increased from 20 pF to 55 pF.
  - Shield method could prevent the testing solution evaporation and made the signal more stable in 1 hr C-t test.



Long-term repeatability verification

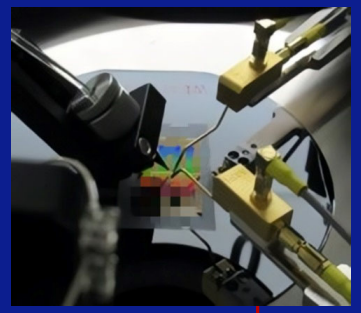
- Using shield method to verify the test platform repeatability and analyze chip characteristic.
  - Three times of the capacitance measurement values remained consistent.

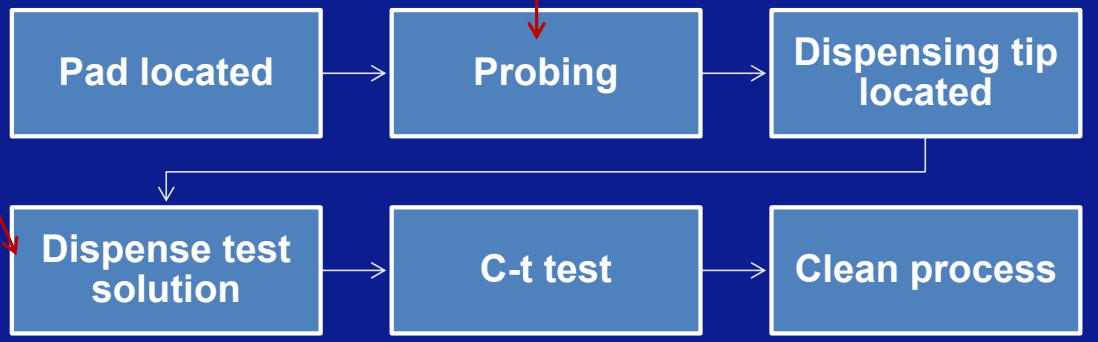


Chip A#004 Test Key2 1M NaCl C-t Test			
Test number	1	2	3
INIT (pF)	9.81	10.1	12.3
AVG (pF)	11.25	10.29	14.80
STD (pF)	1.31	2.12	2.78

Short-term repeatability verification

- According previous experience, optimized the test platform and developed final process.





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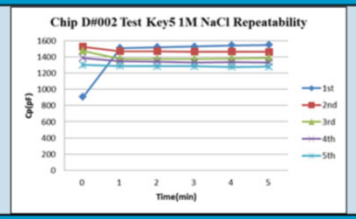
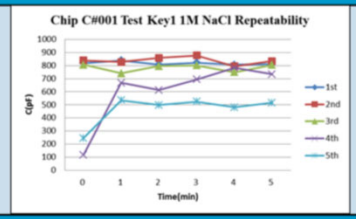
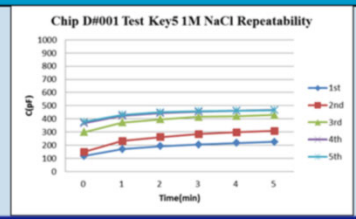
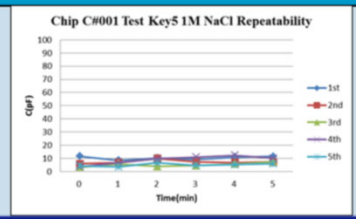
Short-term repeatability verification

- There are 4 groups based on capacitance value, Super High (> 1000 pF), High (1000 pF ~ 500 pF), Medium (500 pF ~ 100 pF), and Low (<100 pF).
  - Results from 30 test keys showed both high stability and accuracy.

Capacitance type	Super high Cap. Type (>1000pF)	High Cap. Type (1000~500pF)
example		
Capacitance type	**Medium Cap. Type (500~100pF)**	**Low Cap. Type (<100pF)**
example		

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Conclusion and discussion

- To meet the wet testing requirements of BioMEMS chips, we developed an integrated platform that ensures reliable measurement accuracy.
- Testing platform developed based on probe station, has the potential for full automation and is currently under development.
- **Supports** our client in enhancing their manufacturing process by analyzing the characteristics of this BioMEMS chip.

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