第85回 FTC研究会 (2022年7月29日)

高精度アナログ IC 試験での熱起電力の影響

Consideration on Thermal Effect for High Precision Analog IC Testing

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Outline

- Research Objective
- Analog IC Testing with Probing
- Thermal Effect by Probe Materials
    - High-precision measurement by DC-AC conversion
    - Calibration Method
- Thermal Effect by Probe Contact Pressure
- Conclusion

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Research Objective

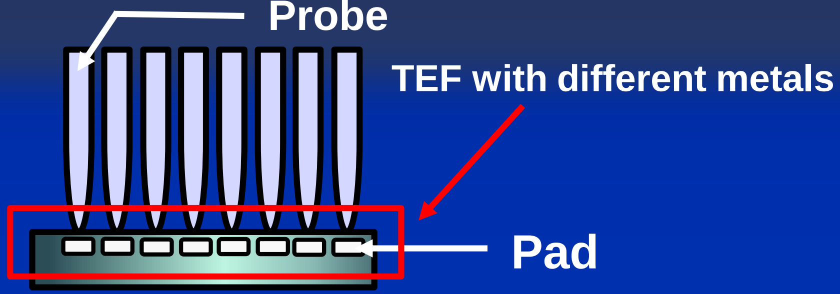
High precision measurement of DUT temperature characteristics with prober

Obstacle: Prober thermal effect (TEF)

Solution

Thermal effect calibration with de-embedding method

- DUT temperature characteristics w/o prober thermal effect
- Constant “prober contact pressure”



※ TEF : Thermo-electromotive force

Our Approach

Thermal effect **calibration** with de-embedding method

(i) "Load" status w/ DUT (auto-zero amp)

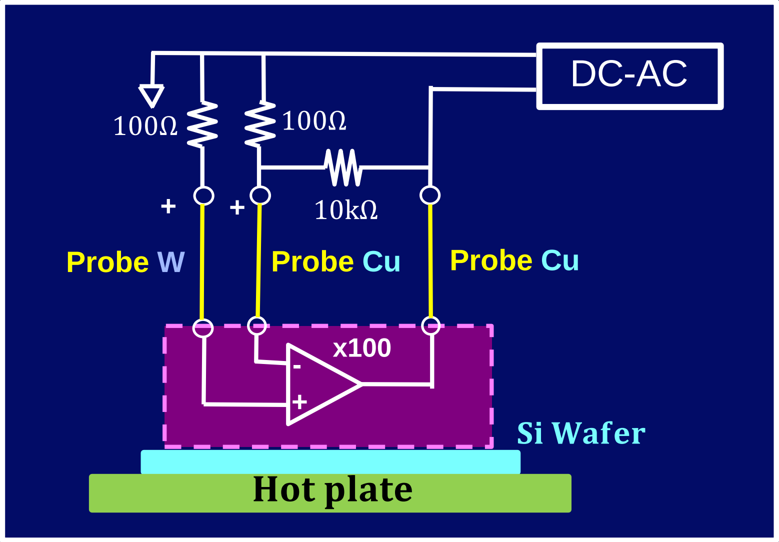
(ii) "Short" status w/o DUT

→ Subtract (i) from (ii)

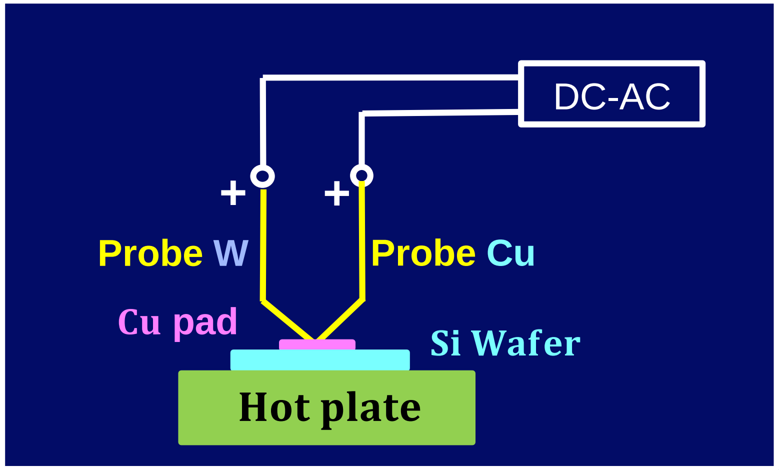
Contact pressure ⇨ TEF fluctuation by 1~20 μV

Scale meter & jack ⇨ TEF fluctuation by ~1μV

"Load" status



"Short" status



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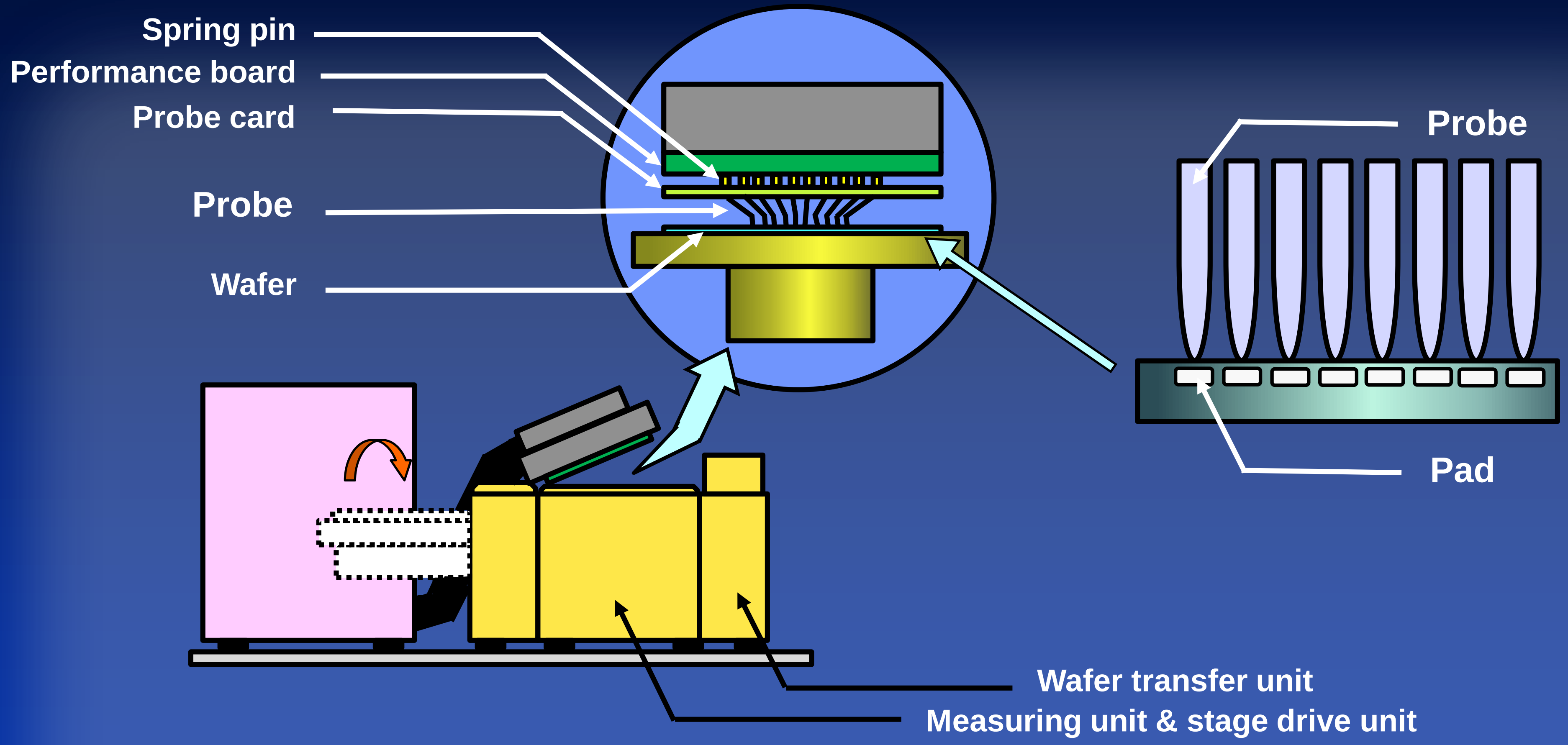
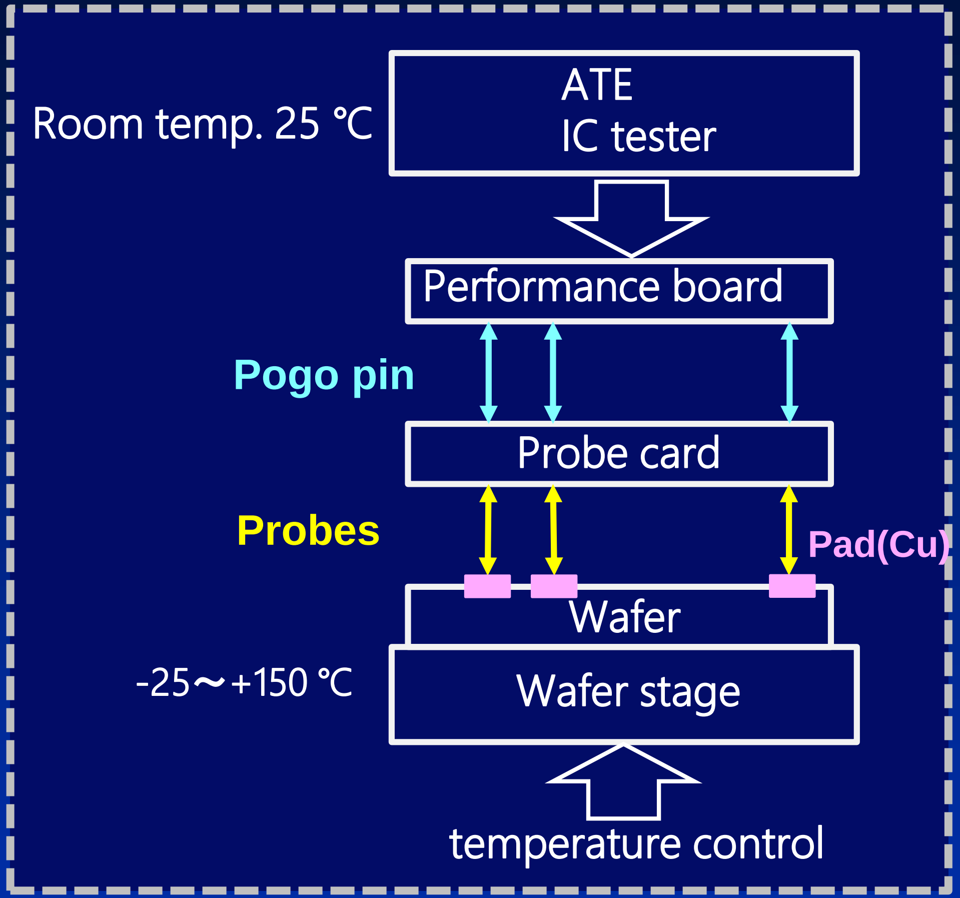
Research Background

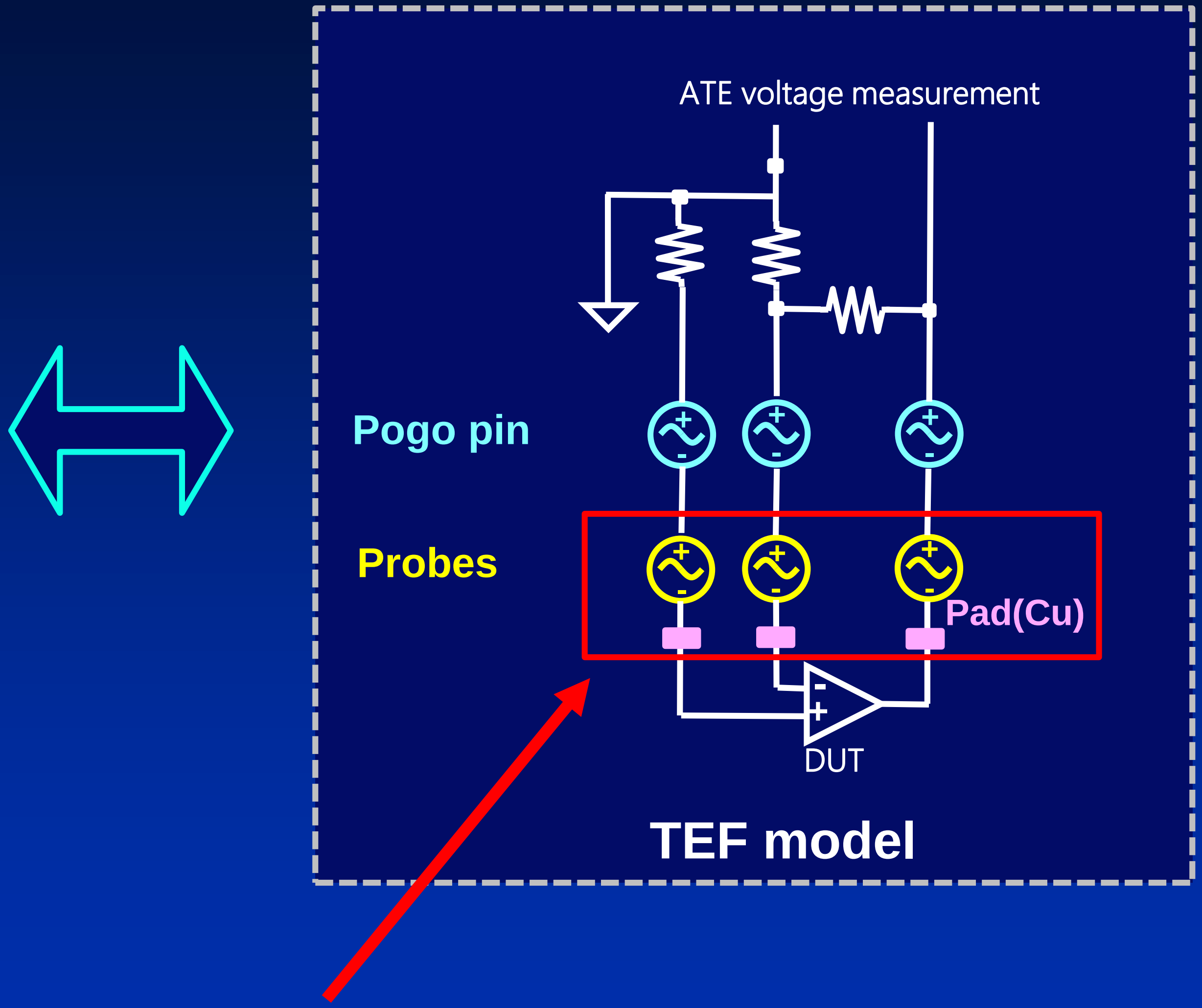


- **Issue for temperature test using prober**

→ **Probe TEF**

TEF Model in Probe Test





TEF due to
different temperature, materials of probes & wafer (PAD)

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Probe TEF Measurement Method

(i) "Load" status w/ DUT

- TEF with probes of different materials
- DC-AC conversion measurement

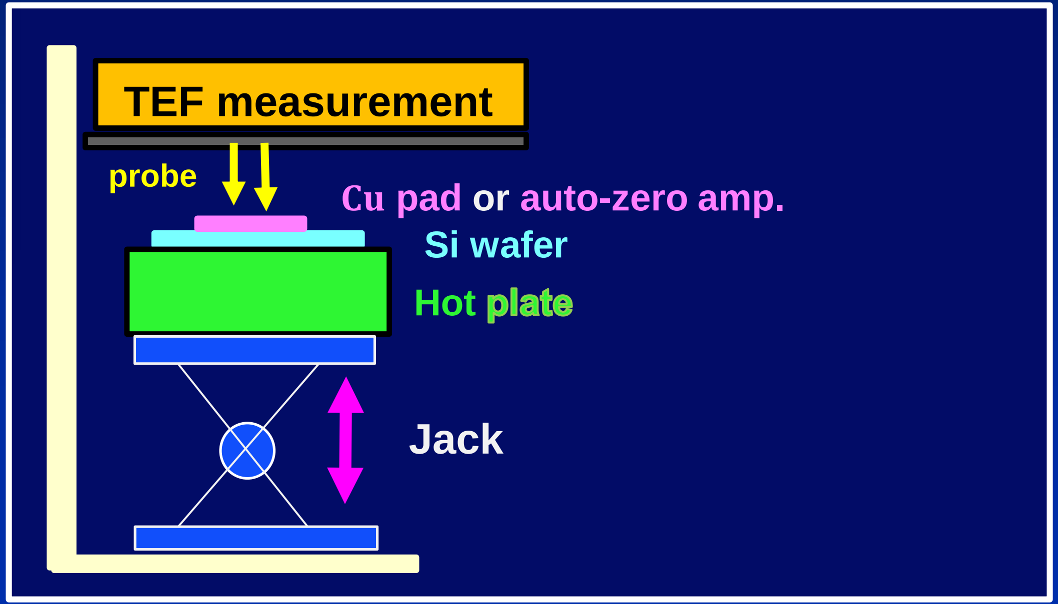
(ii) "Short" status w/o DUT

- Shorting probes

Jack ⇨ Control probe contact pressure

Hot plate

Jack



[1] Yuto Sasaki ,"Accurate and Fast Testing Technique of Operational Amplifier DC Offset Voltage in μV order by DC AC Conversion",2019

Probe Combinations

(i) "Load" status w/ DUT(auto-zero amp)

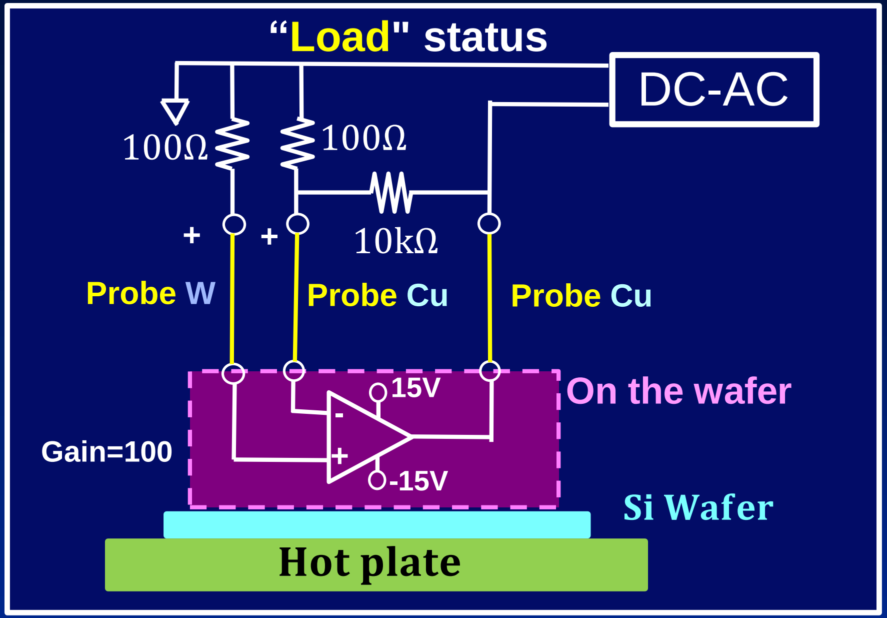
- 3 Probes: W, Cu, Cu
  (tungsten , copper , copper)

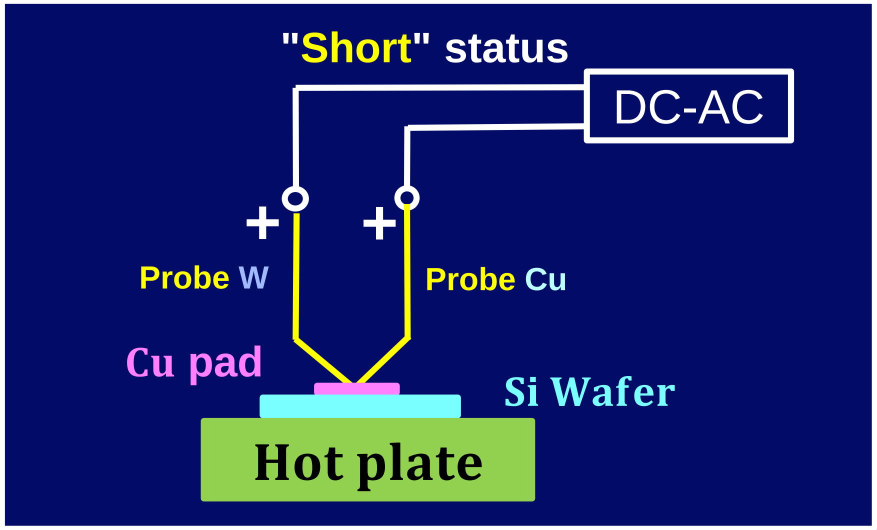
- W, W, W
- Cu, Cu, Cu

(ii) "Short" status w/o DUT

- 2 Probes: W, Cu
  (tungsten , copper)

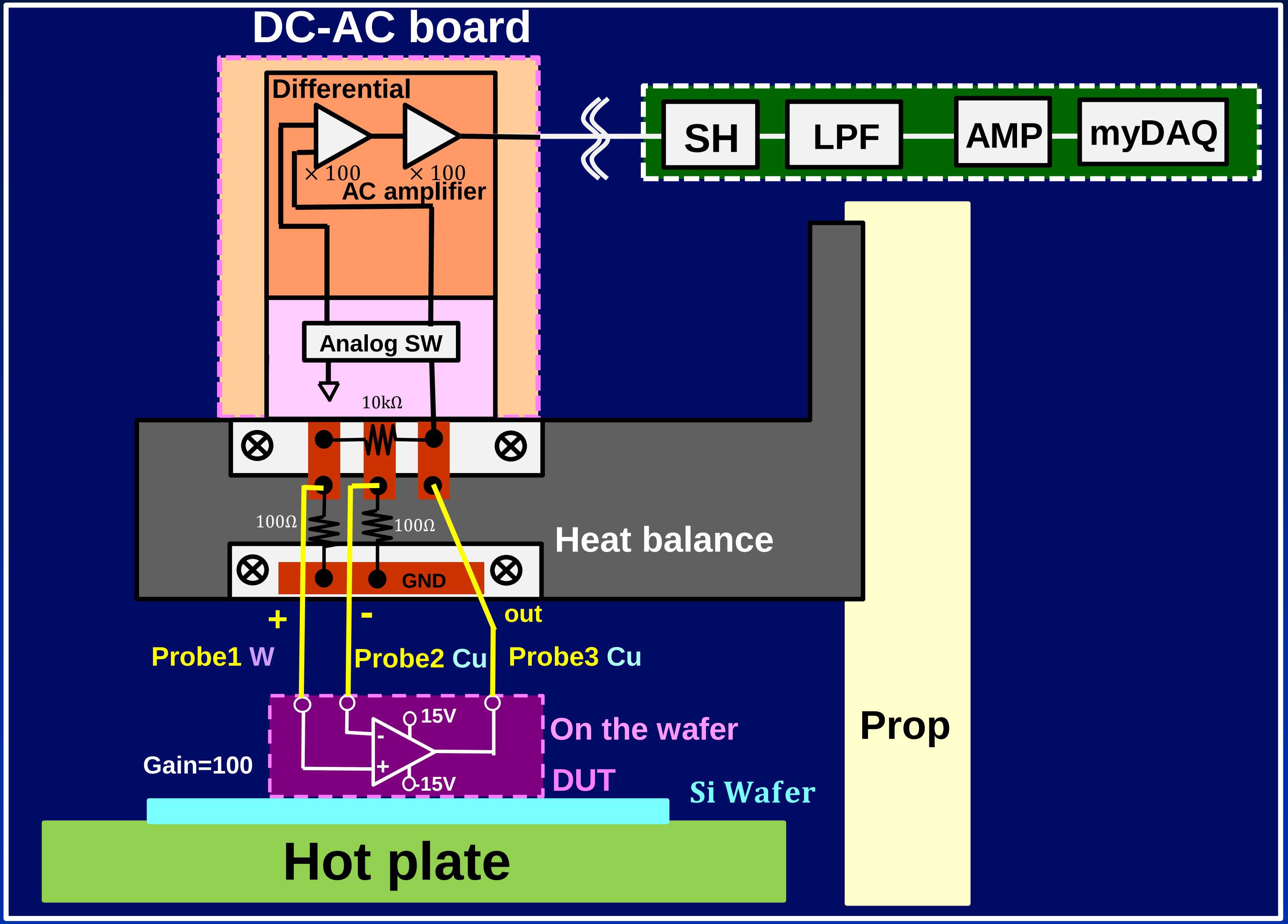
- W , W
- Cu , Cu





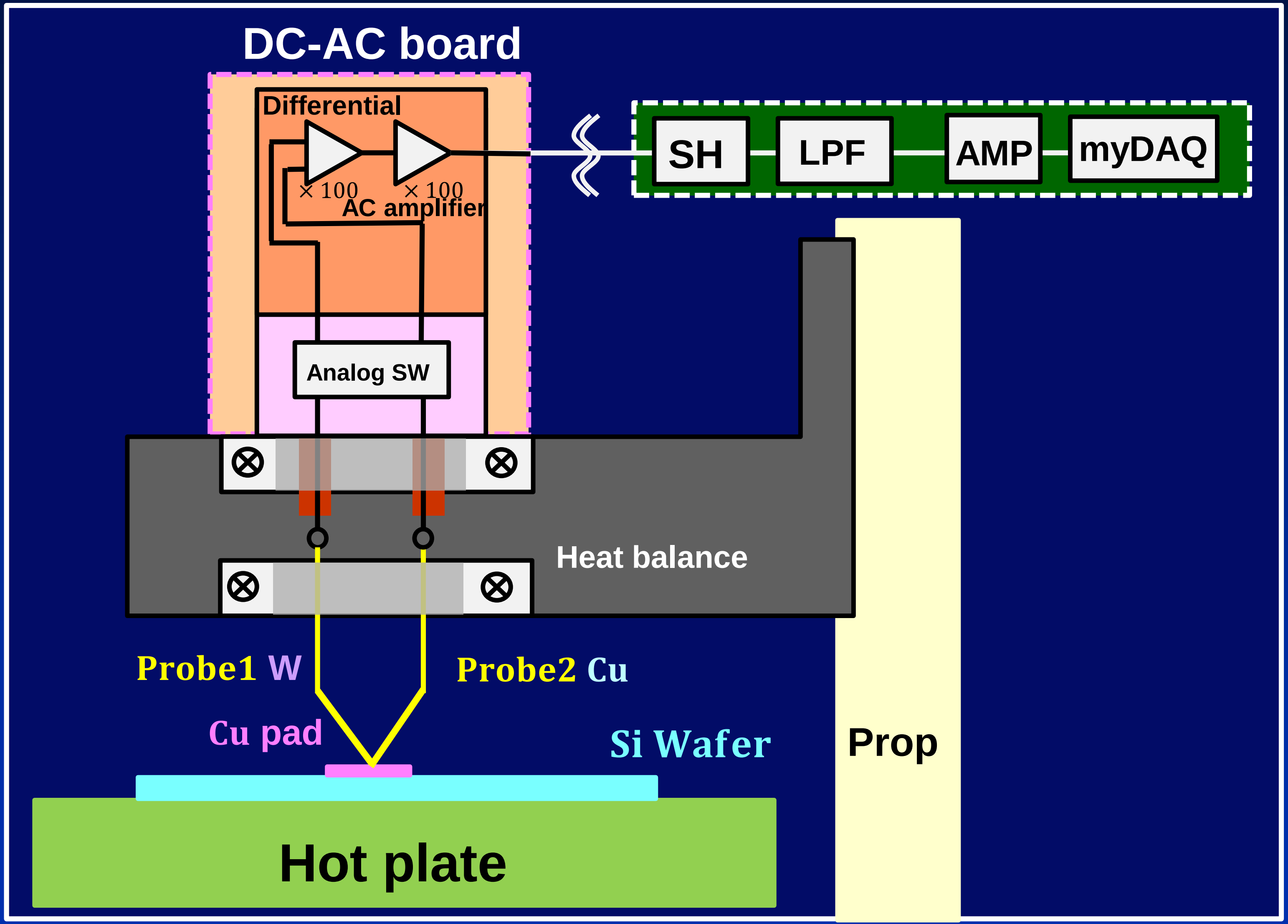
TEF Measurement Using DC–AC Conversion

"Load" status



Measurement TEF Using DC-AC Conversion

"Short" status

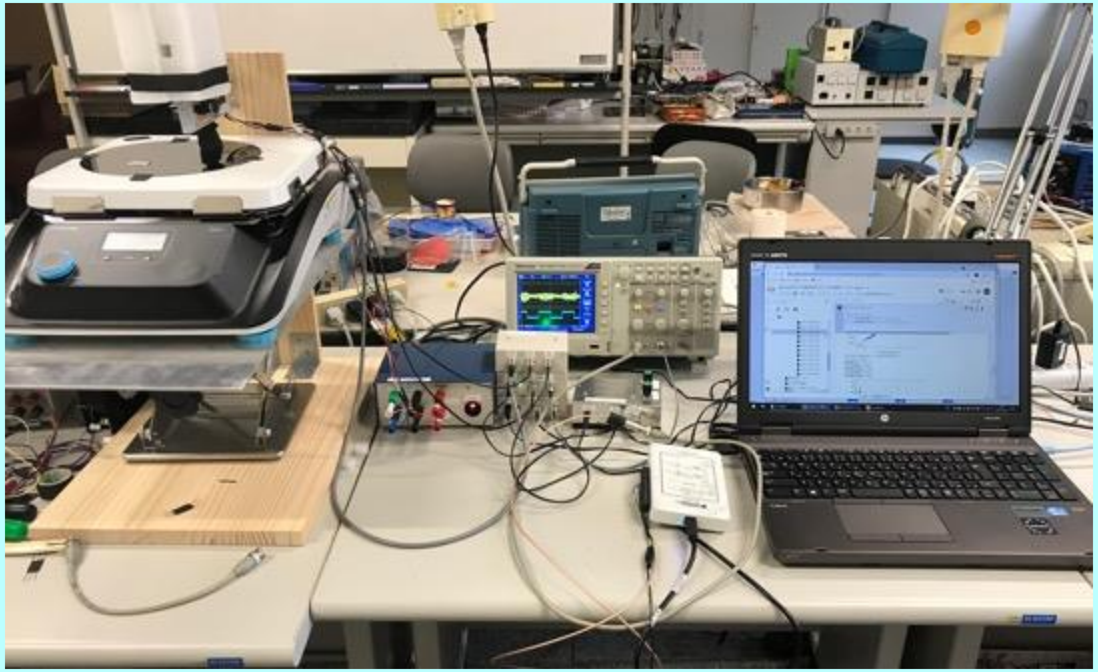


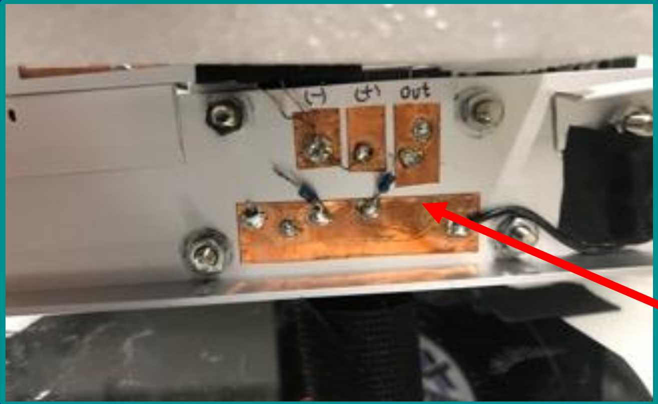
Measurement Environment

■ Severe in heat balance

⇨ Protection of board and probes

■ Probes ⇨ DC-AC conversion ⇨ LabVIEW analysis





■ w/o resistors during TEF measurement

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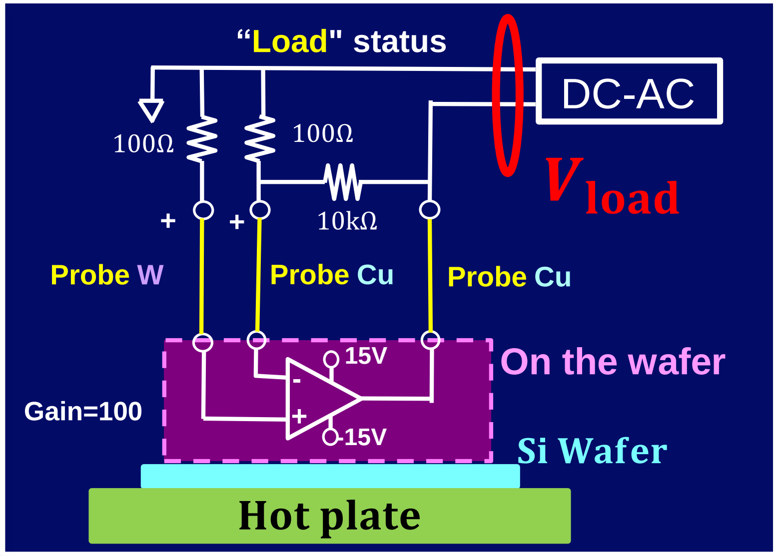
Thermal Effect Calibration with De-embedding Method

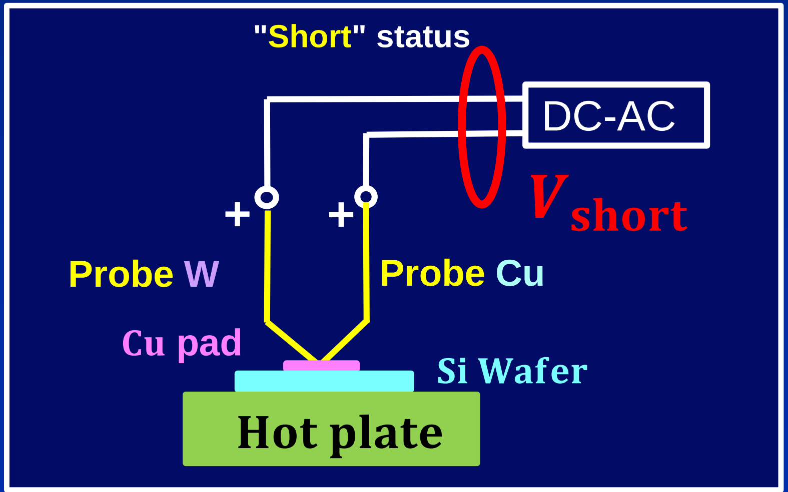
(i) "Load" status w/ DUT (auto-zero amp)

- Gain of DUT ⇨ compensated

(ii) "Short" status w/o DUT

➡ Calibration by subtraction of V_{short} from V_{load}





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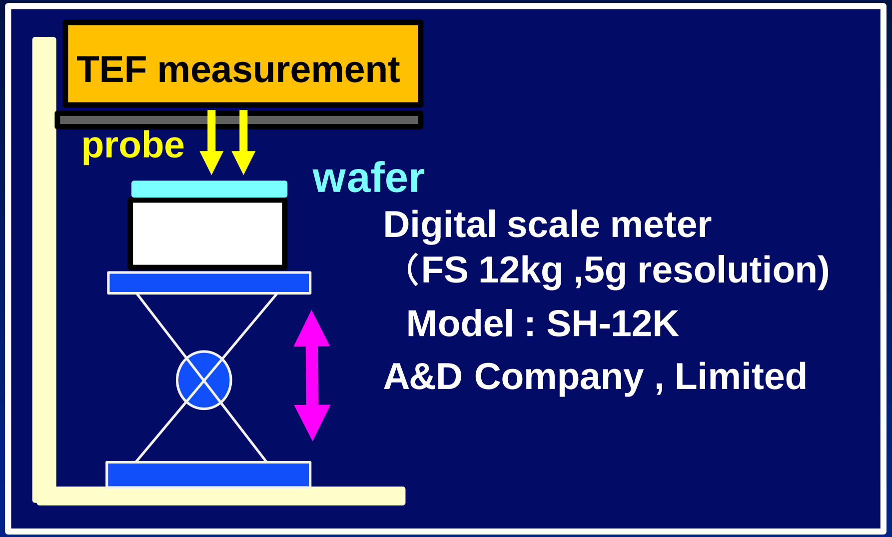
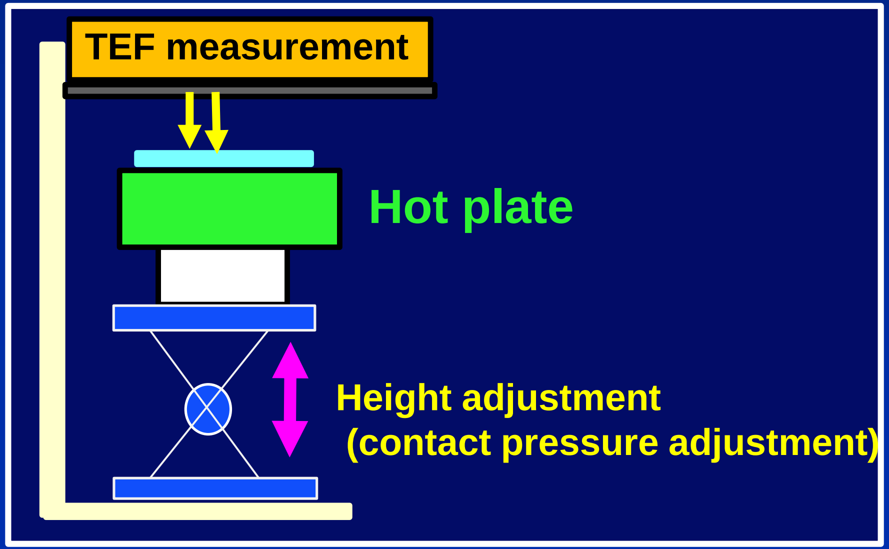
Thermal Effect by Probe Contact Pressure

- **Contact pressure w/o hot plate**
  - ■ Investigate TEF due to contact pressure
  - ■ Measure TEF w/o DUT



- **Contact pressure w/ hot plate**
  - ■ Keep contact pressure constant
  - ■ Measure TEF w/o and w/ DUT

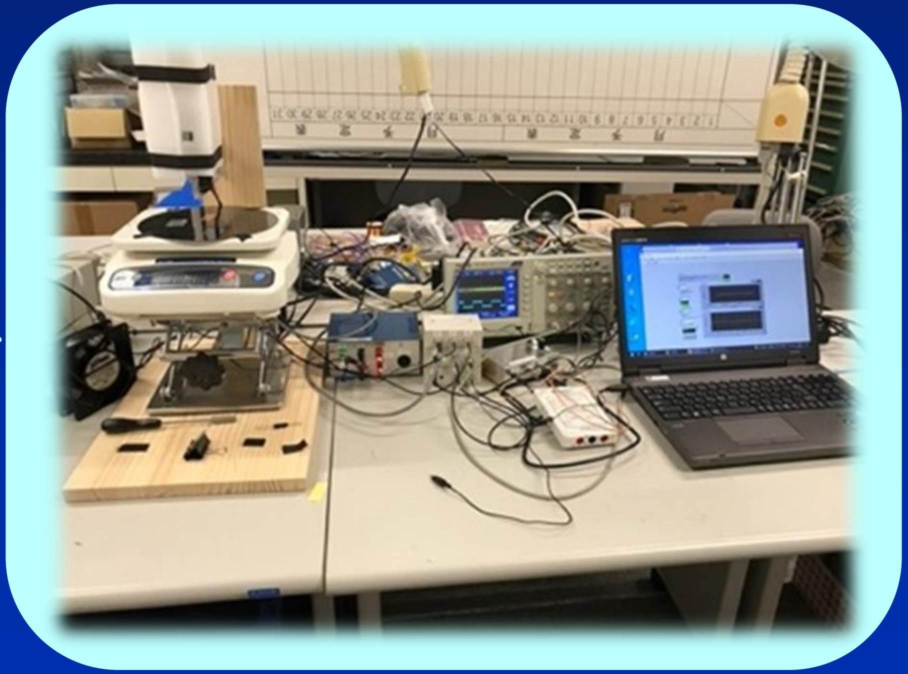


Measurement System: w/o Hot Plate

Contact pressure effect measurement w/o hot plate

- 2 needles for only input part
- Change contact pressure

■ Wafer on scale meter

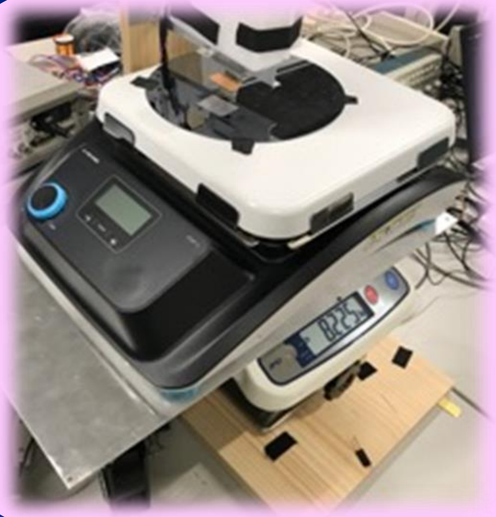


■ Measurement system

Measurement System : w/ Hot Plate

Contact pressure measurement w/ hot plate

- ■ Hot plate on scale meter
- ■ Change temperature & contact pressure



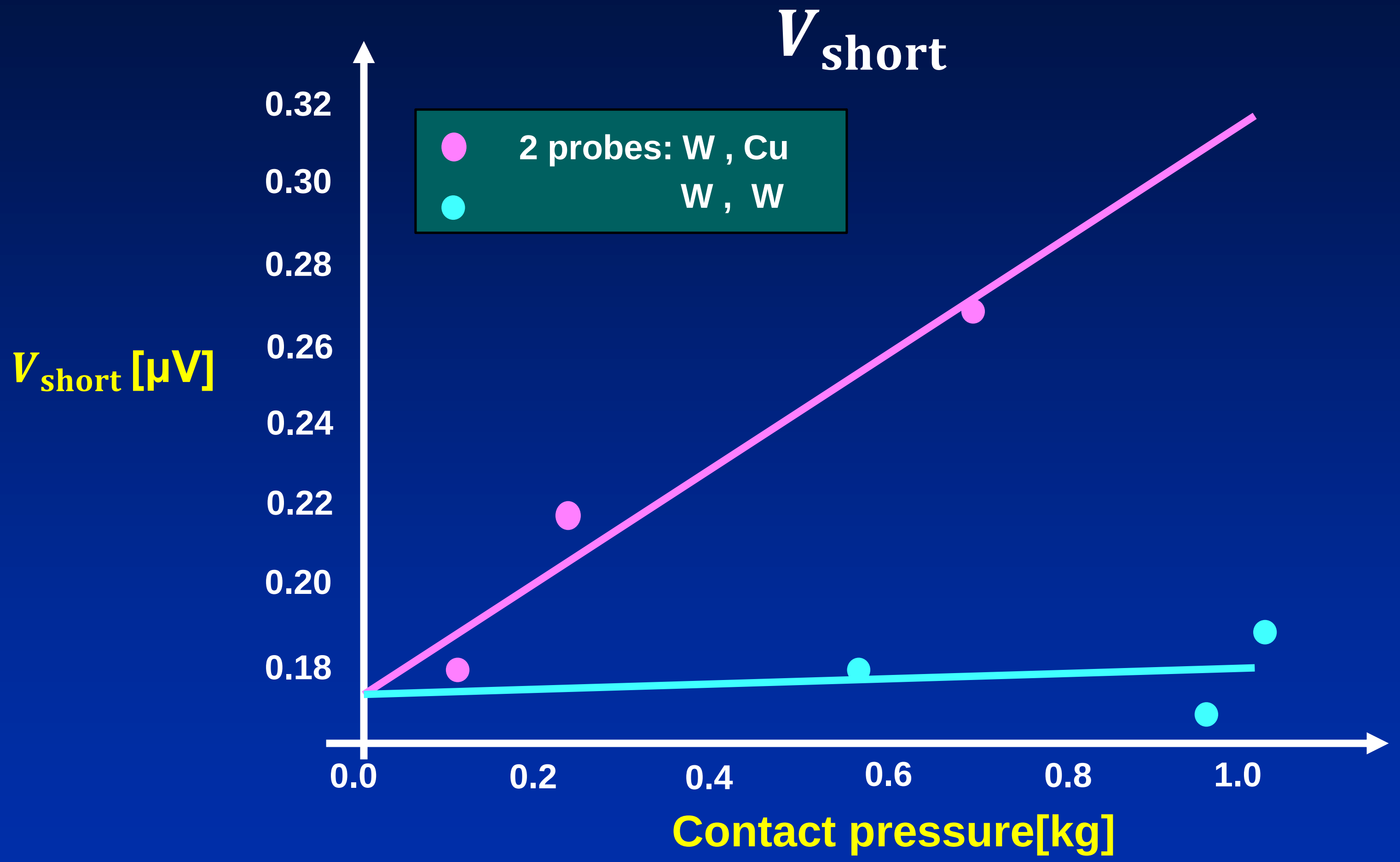
Hot plate: 8.4kg

contact pressure
⇩
FS3.6kg

■ Hot plate & wafer on scale meter

■ Measurement system

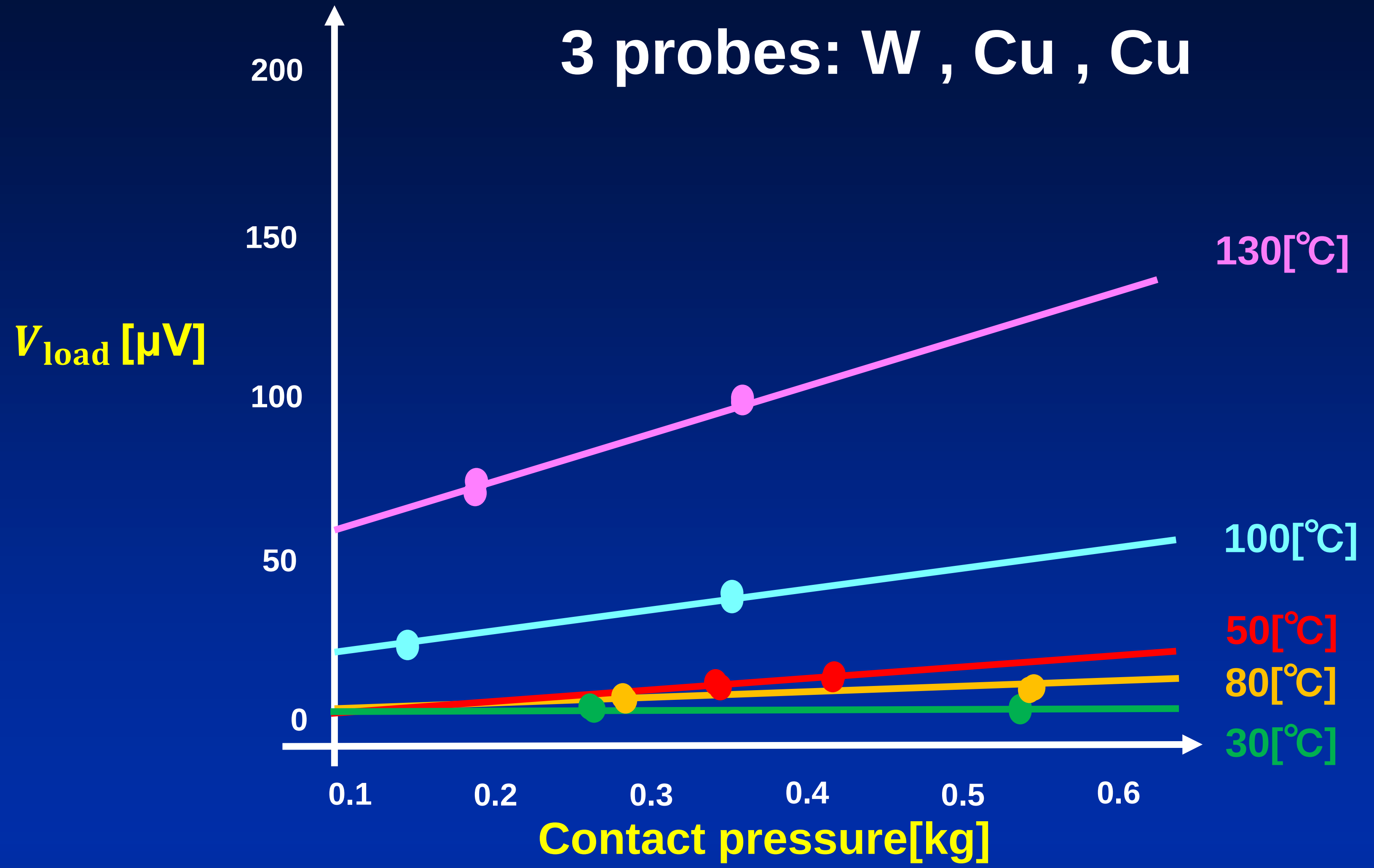
Effect of Contact Pressure w/o Hot Plate



Different probe materials

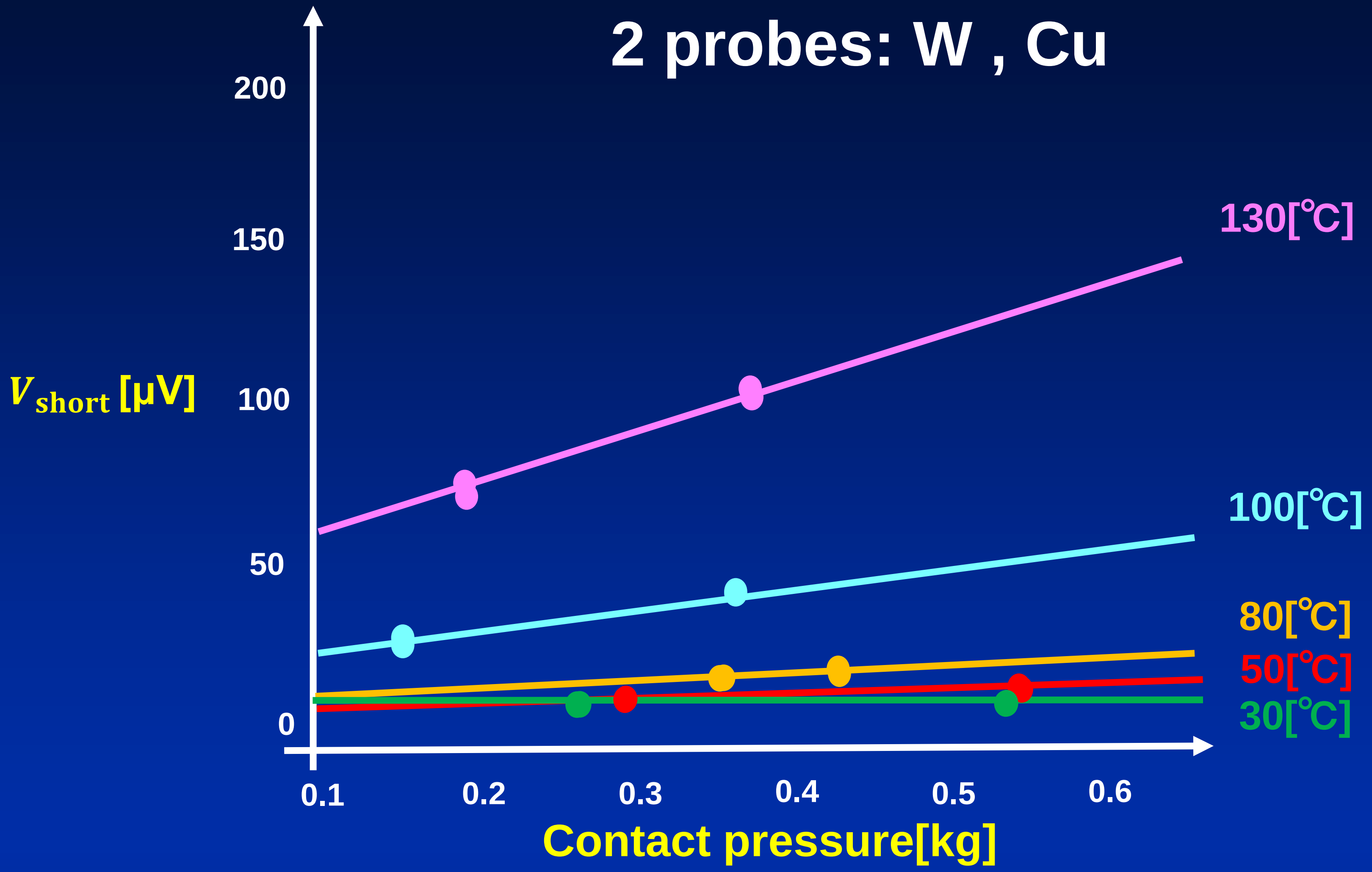
→ **Different TEF change for contact pressure**

Effect of Contact Pressure w/ Hot Plate (V_{load})



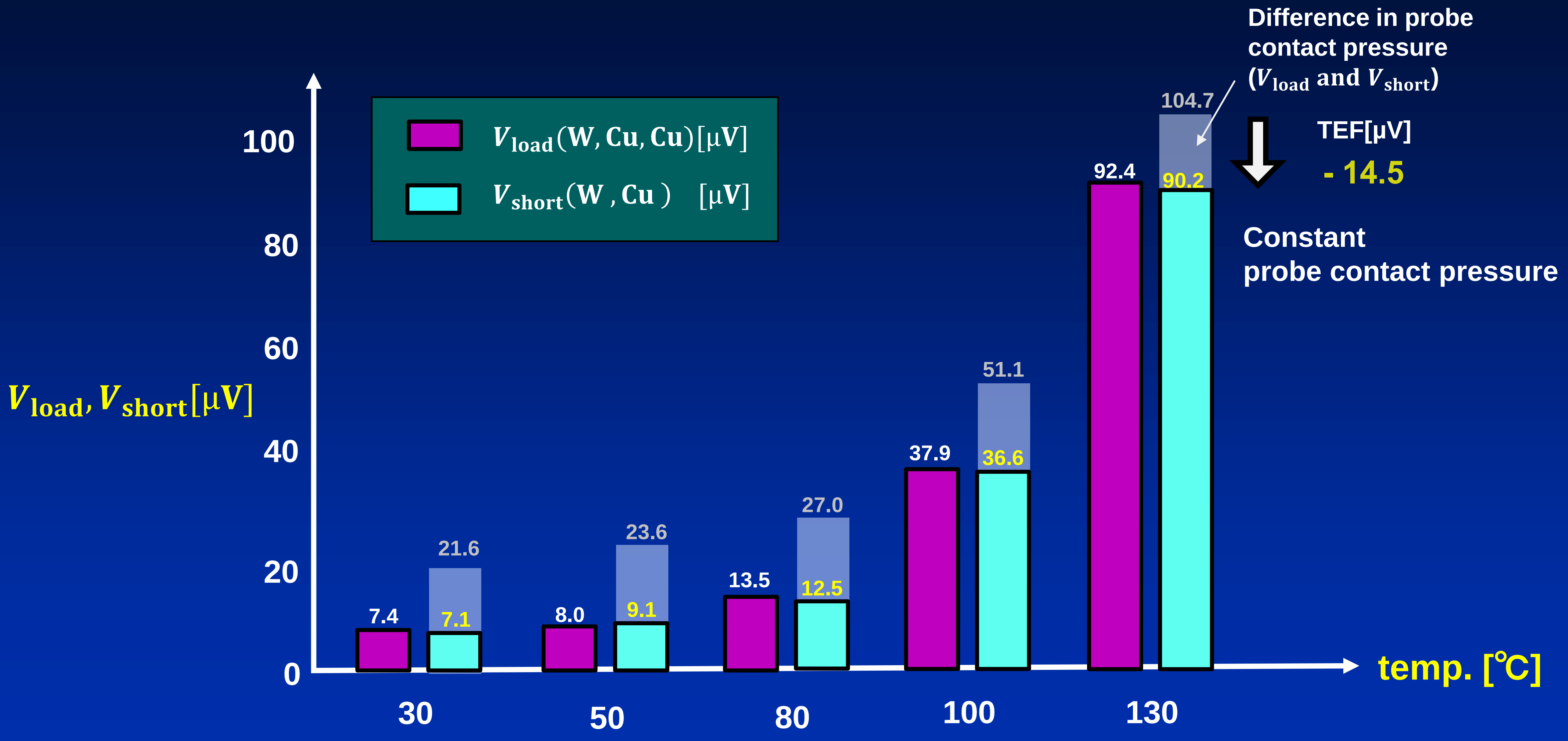
Contact Pressures[kg]		TEF[μV] (100[℃])
+ 0.2	⇨	+ 14.5

Effect of Contact Pressure w/ Hot Plate (V_{short})



Contact Pressures[kg]		TEF[μV] (100[℃])
+ 0.2	⇨	+ 14.5

TEF Measurement Error w/ and w/o DUT



Scale meter to maintain contact pressure ⇨ TEF ~1 μV.

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Conclusions

Thermal Effect for High Precision Analog IC Testing

- **Thermal effect calibration with de-embedding method**
  - Calibrations from w/o and w/ DUT
  - TEF of 70~100 μV between probes
  - DC-AC conversion measurement ⇨ TEF of several μV order
- **Effect of probe contact pressure on TEF**
  - TEF fluctuation by contact pressure change: 1~20 μV

Use scale meter ➞ TEF fluctuation ~1μV.

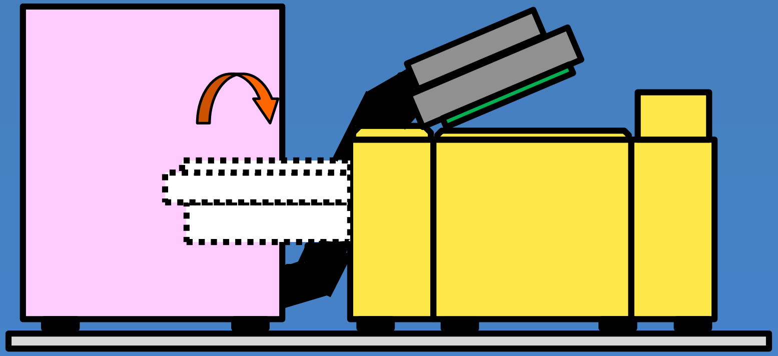
Future Plan

This time

Laboratory experiment

Next Step

Application to mass production ATE system



- "Short" status ⇨ Measured by TEG
- Noise simulation of DC-AC conversion

※TEG : Test Element Group

Thank You for Listening

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Q&A

Q.)

■ What are problems to apply the proposed method to ATE systems at the mass production stage ?

A.)

■ We used only two probes in this experiment.

■ Therefore, there is concern about the accuracy of the calibration when more probes are used.

■ One solution is to add a DUT to this experiment and investigate the effect of increasing the number of probes.

Q&A

Q.)　「熱起電力」とはどの英語か?
A.)　本発表では”TEF : Thermo-electromotive force”と表記している

Q.)　測定後の解析でFFTをするとは?
A.)　■本研究では熱起電力の測定にDC-AC変換を用いている
■DC-AC変換はDC電圧を既知の周波数でチョッピングしてFFTによりチョッピング周波数の成分を観測することで高精度DC電圧測定を実現している
■本研究でのDC測定はμVオーダの計測が求められるため低精度なデジタルマルチメータでは安定した測定が困難

Q&A

Q.)　接触圧の管理により1 μVまで誤差を低減できた
この誤差とは?
A.)　測定ごとのばらつきのことを示している

Q.)　起電力と温度，接触圧の関係について
温度が高い場合，圧力が高い場合に熱起電力が高くなる
その物理的理由は?
A.)　■熱起電力は異なる金属を接触させそれぞれの接触点に
温度差を生じさせたときに電流が流れる
「ゼーベック効果」によるものである
■高温の場合は室温との温度差が大きくなるため
電流が増加し熱起電力が高くなったと考えられる
■接触圧が高い場合に熱起電力が高くなる理由は検討中

Q&A

Q.)　今回は疑似的なプローバ装置による実験だった
実際のプローバとの誤差は?
A.)　検討中

Q.)　従来のプローバ試験においての熱起電力の対策は?
A.)　製品のスペック保証の範囲を大きくして対応していた

Q&A

Q.)　熱起電力は、DC電圧として測定しているように見えました。そうすると、それを使ってCALした結果、ばらつきが減る、という理由がよく分かりませんでした。
つまり、DC電圧を差し引くのであれば、分布の平均値が変わるのであって、標準偏差（ばらつき）は、変わらないように思いました。

A.)　Load statusとShort statusそれぞれの
分布の平均値は一定
平均値を差し引くCALの結果は一定になりそう
測定回数を増やせばばらつきの影響を低減可能であると考えられる
測定回数増加によるコスト増の懸念があり
接触圧の管理によるコストとの兼ね合いを今後検討