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A Study on CCC of Fine Pitch Vertical Probe; Simplified CCC Formula and its Verification

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Overview

- Background
- CCC Methodology Review
  - ISMI(09'), Current spike(10'), FFI(11')
- Former CCC Formulae
- Probe CCC Test under Varying Temperature: T-CCC
- Correlation
- Conclusion
- Future Work

Background

- **Shrinking probe pitch**
  - Leads to the probe fusing & burnt
  - Platinum group metals have limitation for the probe
- **Expectation of high temperature performance**
  - Requires higher CCC value with fine pitch
  - Requires more thermal reliability
- **Previous CCC studies were focused on "CRES"**
  - Focus moved to "Temperature" and its relative parameters
  - A study of temperature dependent CCC did not presented in SWTW so far

CCC Methodology Review

- **ISMI (SWTW, 2009)**
  - Step ramp after steady current
    → 20% force reduction test
- **Current spike & Lifetime reliability test (SWTW, 2010)**
  - Step ramp after pulse current
    → Current spike CCC testing
    → Lifetime reliability CCC testing
- **FFI standard (SWTW, 2011)**
  - Continuous ramp
    → Ramp up current until fail
    → Long term stress

Former CCC Formulae

- **Joule heating**
  - Joule heating equation

$$P = I^2 \times Cres$$

- **Joule heating upon temperature variation**
  - Joule heating equation **for temperature dependant**

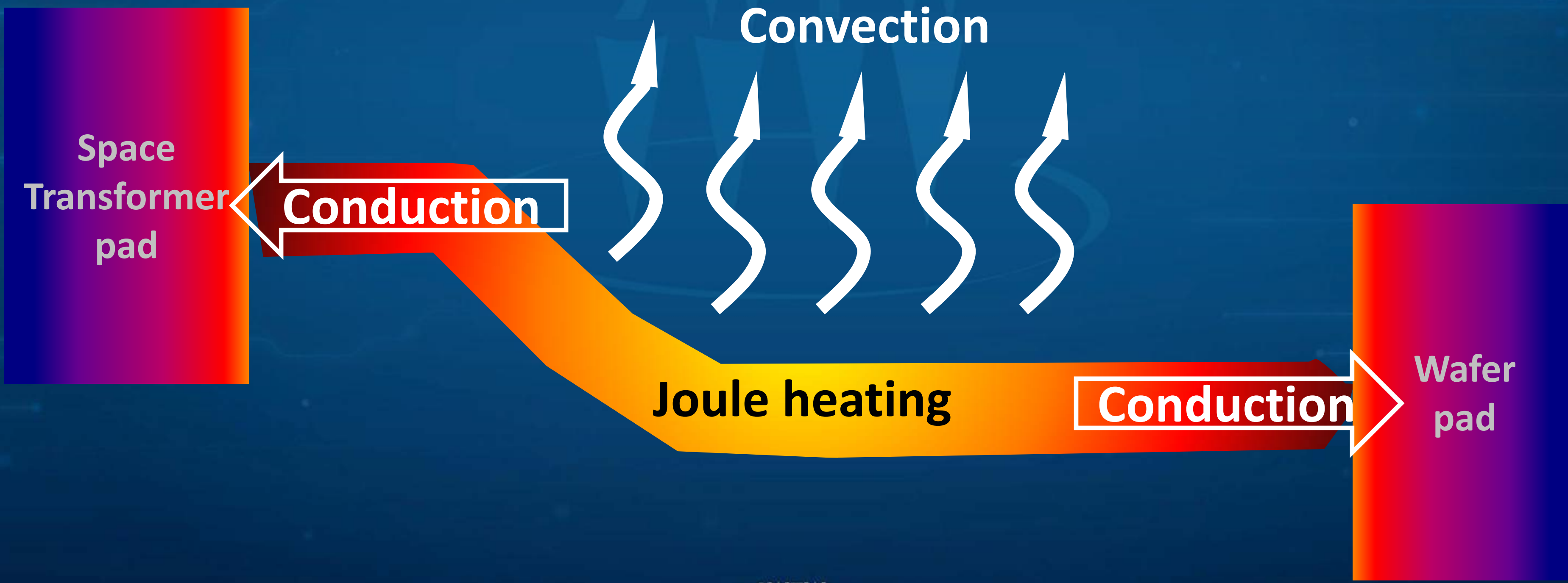
$$\Delta V = RI = [\rho_0 + \alpha(T - T_{ref})]\frac{L}{A} I$$

- **Power system design**
  - CCC predicted equation

$$I = \frac{A}{L}\sqrt{\frac{k}{\rho}}\sqrt{\Delta T}$$

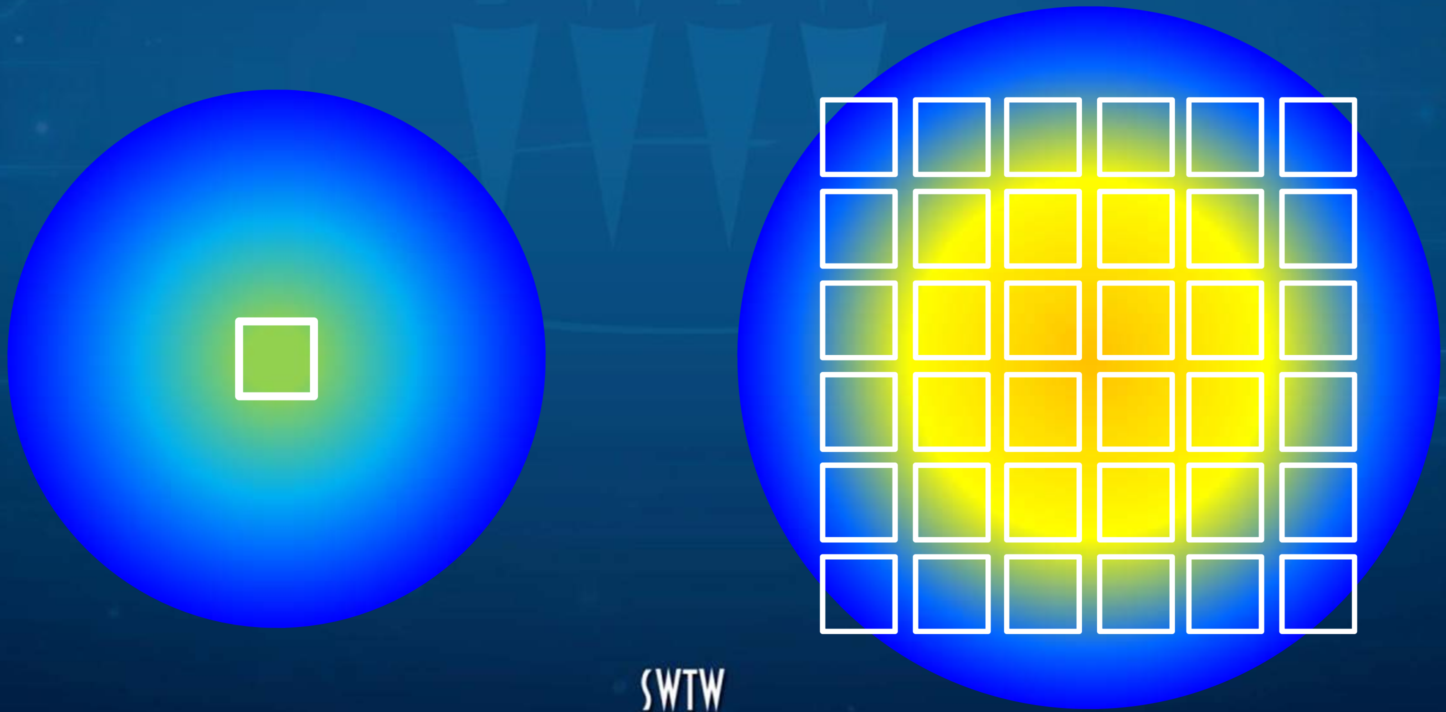
Temp-CCC (T-CCC) Mechanism

- **T-CCC mechanism in terms of a probe**
  - The heat generation equals to the dissipation
  - $Q_{generated} = Q_{dissip.convection} + Q_{dissip.conduction}$



In case of pin array

- **T-CCC mechanism of the array probes**
  - Temperature gradient when the probes form array
  - Effective factor:
    - Coefficient of convection (*h*)
    - Ambient temperature (T_a)



T-CCC Formulation

- **New CCC formula including temp. variation: T-CCC**
  - T-CCC parameters :
    - Resistivity @Initial temperature (ρ_0)
    - Diameter (d)
    - Probe length (L)
    - Temperature (T_{ref})
    - Thermal diffusivity (α)
    - Thermal conductivity (k)
    - Thermal convection coefficient (h)
    - Multiplier (β)

$$I = A\sqrt{\frac{\Delta T}{\rho_0 + \alpha(T - T_{ref})}} \cdot \sqrt{\frac{k\beta^2}{L^2} + \frac{4h}{d}}$$

T-CCC Formulation

- **New CCC formula including temp. variation: T-CCC**
  - T-CCC parameters :
    - Resistivity, function of temperature (*ρ*)
    - Probe length (*L*)
    - Temperature (*T*)
    - Area (A)
    - Simplified multiplier (*β′*)

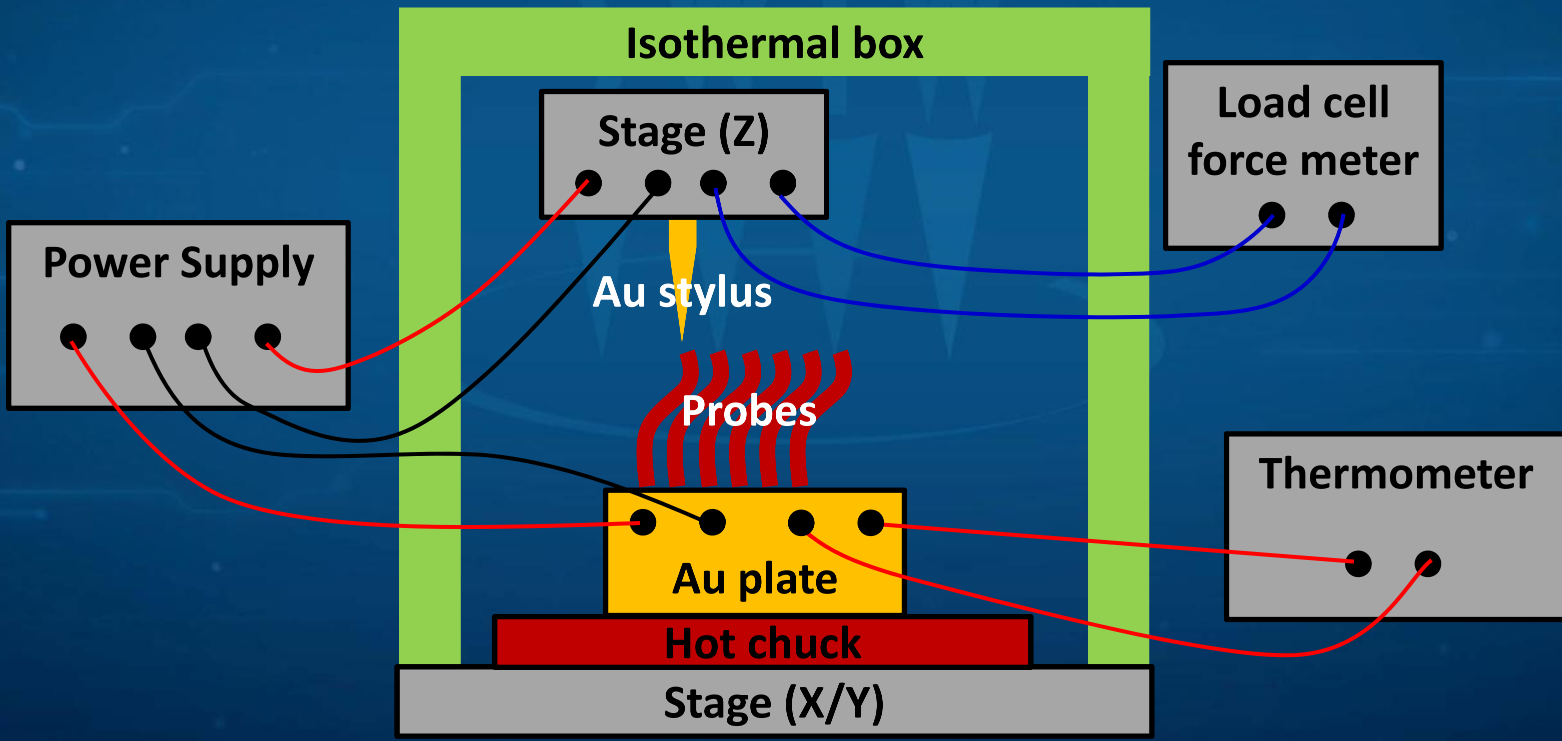
Where *k, h* are considered as constant due to:

- Thermal conductivity (*k*) is unchanged in 25°C to 100°C
- The coefficient of convection (*h*) is negligible.

$$CCC = \beta' \frac{A}{L} \sqrt{\frac{1}{\rho(T)}}$$

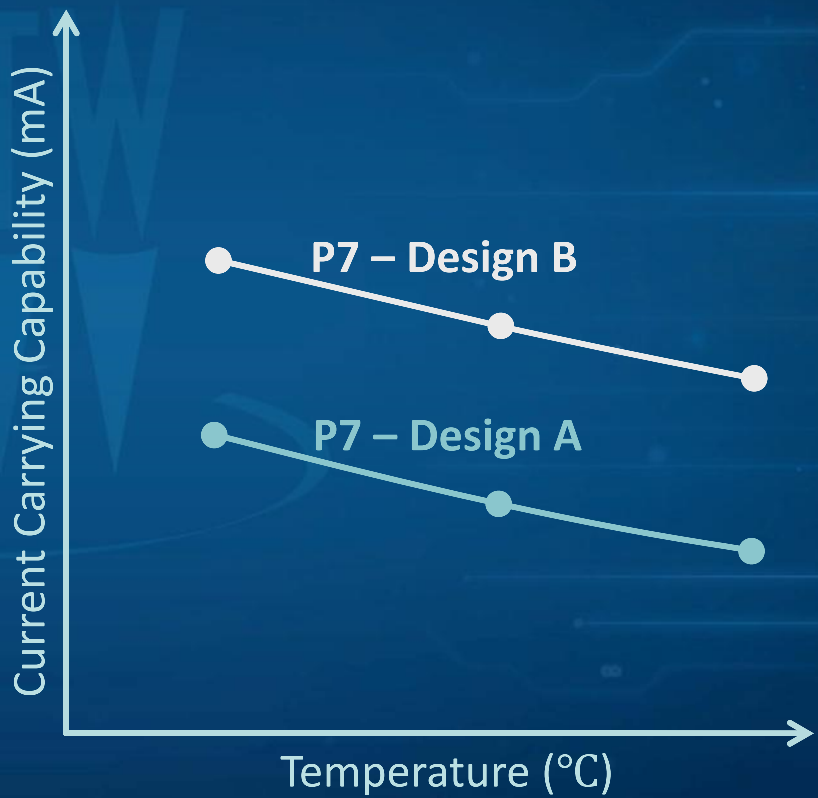
T-CCC Test

- **T-CCC measurement setup**
  - ISMI CCC test setup + Temperature control system



CCC vs. Temp of P7
(ISMI guideline)

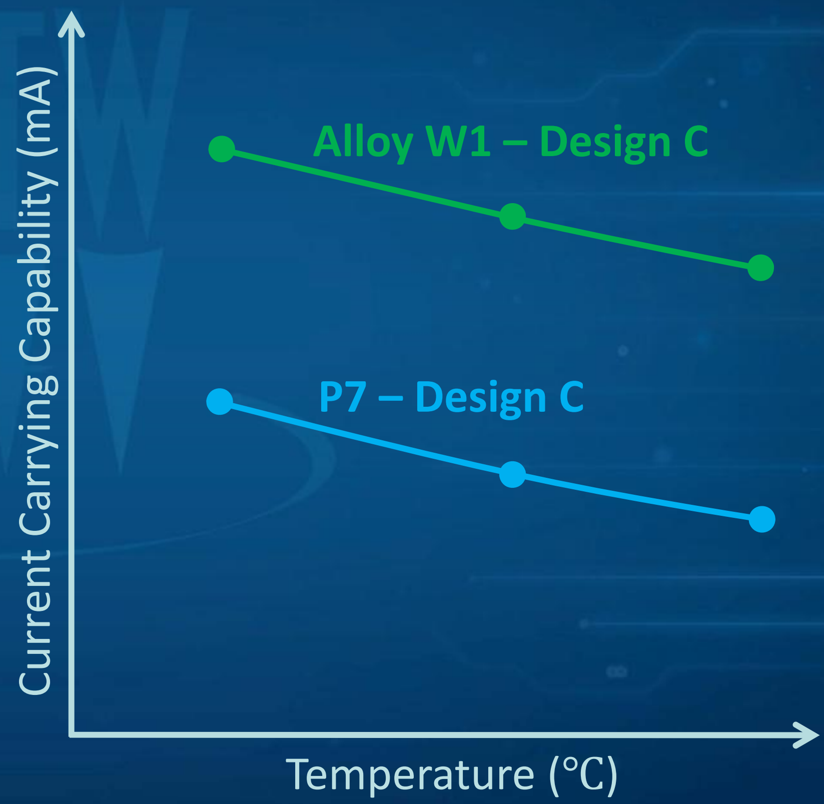
- **T-CCC test temperature**
  - RT, 60°C and 90°C
- **Results**
  - CCC ↑ as probe dia. ↑
    - *CCC ∝ A*
  - CCC ↓ as temperature ↑
    - $CCC \propto \rho^{-1/2}$
  - Determinants:
    - Probe tip diameter
    - Temperature is highly relative to resistivity
    - The resistivity affect CCC



CCC vs. Temp of Alloy W1
(ISMI guideline)

- **T-CCC test temperature**
  - RT, 60°C and 90°C
- **Results**
  - CCC ↑ as probe dia. ↑
    - *CCC* $\propto$ *A*
  - CCC ↓ as temperature ↑
    - *CCC* $\propto \rho^{-1/2}$

Alloy W1 has higher CCC

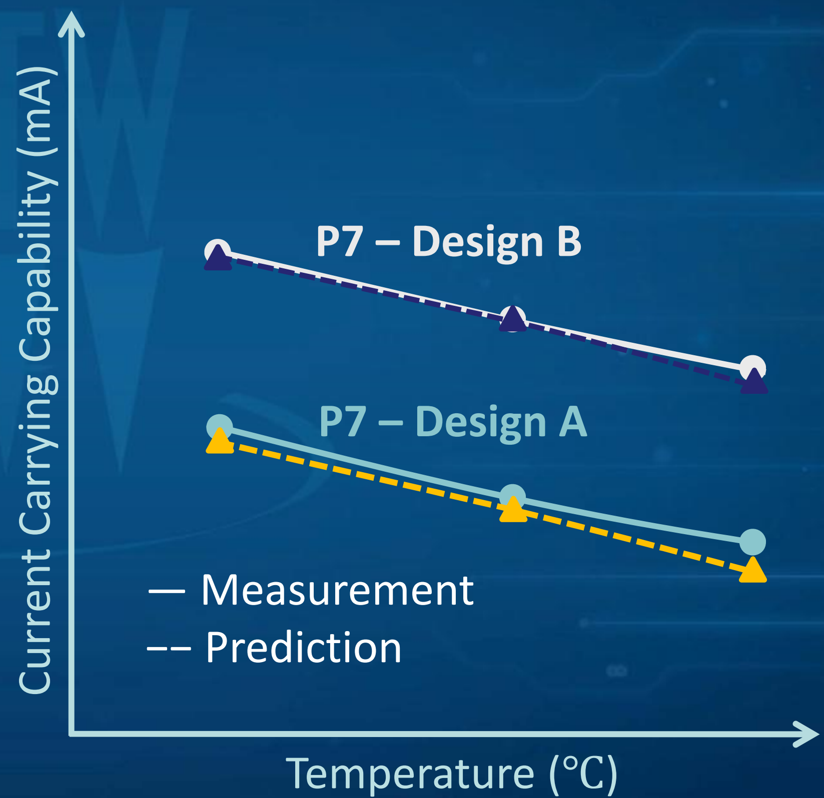


Correlation of P7

between experimental data and formula

- **Error of CCC prediction for P7 probe**
  - Error range: ≤ 8%
    - Probe length uniformity
    - The other geometric error
    - Resistivity tolerance

- **Difference of *k***
  - $k \leq 3\%$
  - Almost constant at RT to 90°C



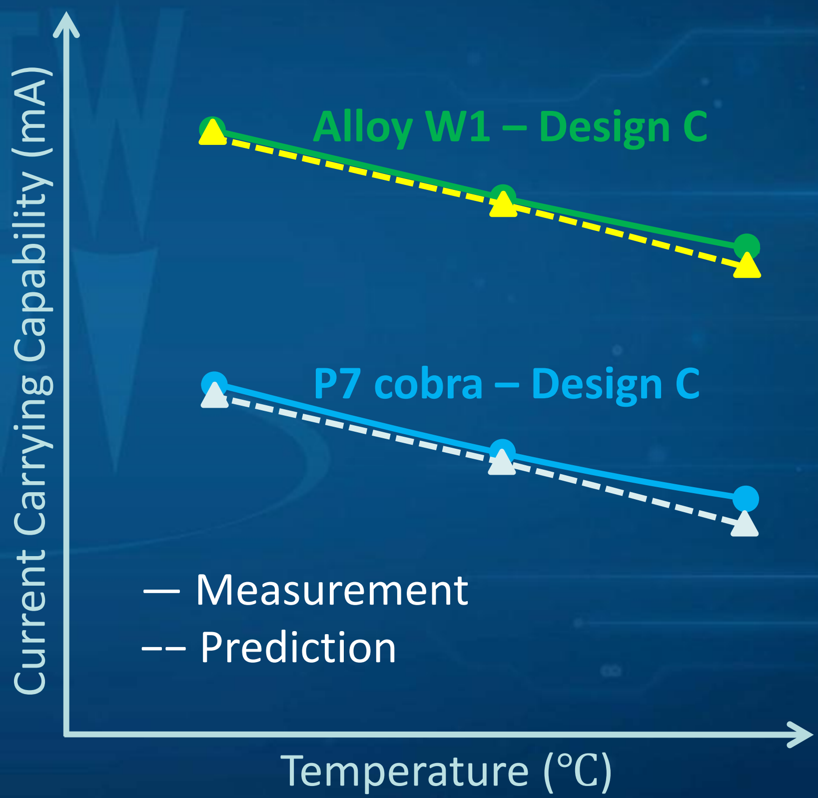
Correlation of Alloy W1

between experimental data and formula

- **Error of CCC prediction for "Alloy W1" probe**
  - Error range: ≤ 4%
    - Probe length uniformity
    - The other geometric error
    - Resistivity tolerance

- ***Decisive parameter:***

Resistivity!



Conclusion

- The high density of probe pin array causes the increasing temperature in the center region.
  - CCC decreased as the resistivity increased.

- Resistivity of the material was a critical factor in T-CCC formula.
  - Temperature ↑ → Resistivity ↑ → CCC ↓
  - Thermal conductivity, *k* was neglected
  - Convection, *h* was neglected

- Geometric factors–diameter and length of the probe–were also contributed the CCC result
  - Assumed all of the probes were identical

Conclusion

- Willtechnology designed "Alloy W1" showed much higher CCC than P7 probe

- Calculated CCC values by T-CCC formula were similar to the experimental results.
  - The effect of neglected parameters in the T-CCC formula is less than 8% of error

	Predicted error (25°C~90°C)
Design A (P7)	< 8%
Design B (P7)	< 4%
Design A (W1)	< 4%

Future work

- Effect of probe pin array (i.e. array size, pitch, and clearance) in T-CCC
- A research of parametric formulation for a major parameter, CRES
- Effect of surface coating in T-CCC
- A research of CCC variation depending on tip shaping

Reference

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