CCC Analysis and Prospect of Iridium Probe

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Tad Rokkaku Probe Innovation USA

0. Abstract

(1) According to Basic Theory, Heat Balance between Heat Generation and Heat Emission was analyzed.
As the result, in case of probe of round cross section,
it has ben found that CCC is proportional to (Diameter)^ (3/2). ---- Equation (1-5) in page 3.

(2) To estimate CCC of different diameter, based on the experimental data,
the way to estimate CCC has been found.

(3) In case of Cobra Probe, as Heat Emission Area is larger than round cross section probe
due to pressed ribbon, CCC was larger than the value estimated by equation (1-5).

(4) In case of Wire Probe with insulating coating, CCC is smaller than the value estimated by equation
(1-5). In this case, CCC is proportional to (Diameter)^(5/2).
This seems to be the influence of insulating coating which hampers heat emission.

(5) The way to estimate CCC of iridium has been analyzed.
It has been found that CCC of iridium probe is 10% larger than Rhodium probe due to the large
difference of melting point temperature.

(6) CCC data table and graph have been made; Figure 1-1 and Table 1-2.

1. How to estimate CCC of different diameter based on experimental data

1.1. Heat generation of conductor

H = UL
= L* I^2*R ---(1-1)

1.2. Heat radiation of conductor

q = h * S * (Ts - To) ----------(1-2)

1.3. Heat Balance

H = q
And set S = L * π * d
Then (1-3) is obtained
In next page.

Table 1-1 Symbols and contents

Symbol	Name	Dimension
H	Total heat generation	W
L	Length of heat radiation object	m
U	Heat generation per unit length	W/m
I	Current	A
R	Resistance per unit length	Ohm/m
ρ	Resistivity of conductor material	Ohm・m
q	Heat Flow	W
h	Heat transfer rate	W/m^2/℃
S	Area of heat radiation object	m^2
d	Diameter of heat radiation object	m
A	Area of conductor cross section	m^2
Ts	Surface temperature of object	K
To	Neighboring temperature	K

$$I = \sqrt{h * \pi * d * (Ts - To) / R} \quad \text{-----------} \quad (1\text{-}3)$$

Conductor resistance = R * L = ρ * L/A
Therefore Resistance per unit length

$$R = \rho / A = 4 * \rho / (\pi * d^2) \quad \text{--------------} (1\text{-}4)$$

Substituting equation (1-4) into equation (1-3), equation (1-5) is obtained.

$$I = h * \pi * d * (Ts - To) / R$$

$$= \pi * \sqrt{h * d^3 * (Ts - T0) / (4 \rho)} \quad \text{-------} \quad (1\text{-}5)$$

From equation (1-5), we know that **CCC is proportional to (Diameter)^(3/2).**

We have CCC data of H3C in case of diameter 3 mil, CCC data of Rhodium in case of diameter 0.029mm.
In section 2, it is explained that CCC of Iridium is estimated about 10% larger than CCC of Rhodium.

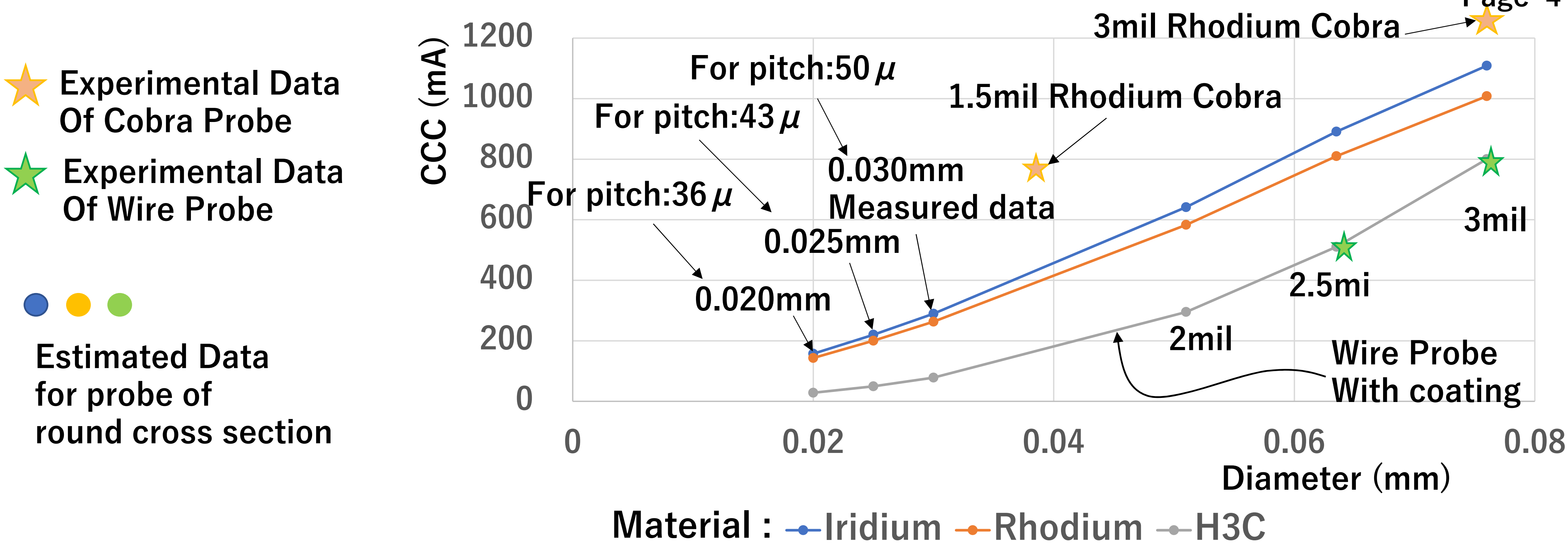

Figure 1-1 CCC estimation based on experimental data and theory

According to the equation equation (1-5) in the former page, CCC is proportional to (Diameter)^(3/2).

In case of Cora Probe, heat emission area is expanded by ribbon, resulting in a larger CCC shown in Figure 1- 1 as mark ★.

In case of Wire Probe, CCC seems to be proportional to (Diameter)^(5/2).

This seems to be the influence of insulating coating which hampers heat emission. If the thickness of insulating coating is the same despite the size of diameter, the smaller diameter, the lower CCC.

Table 1-2 gives numerical data of CCC.

It is obvious that Wire Probe made of H3C and insulating coating is not advantageous for the following reason:

(1) Electrical resistivity of H3C is high. (11～13 $\mu\Omega\cdot cm$)

(2) Insulating coating hampers heat emission, resulting in a lower CCC.

Table 1-2 Numerical data of CCC

Diameter (mm)	0.076	0.0635	0.051	0.03	0.025	0.02	
Diameter (mil)	3	2.5	2	1.18	1	0.787	
Iridium (Round probe of no coating)	1109	891	641	289	220	157	CCC is proportional to (Diameter)^(3/2)
Rhodium (Round probe of no coating)	1008	810	583	263	200	143	
H3C (Round probe with insulating coating)	800	510	295	78	50	28	CCC is proportional to (Diameter)^(5/2)

2. How to estimate CCC of Iridium

In our CCC test using Rhodium straight pins, we could observe the following phenomena:

(1) Increasing current little by little, just after CCC limit where contact force is down 20%, Rhodium wire melted and was broken.
(2) It seems that the wire temperature at CCC limit is close to melting point as Rhodium wire is melted and broken just after CCC limit.

It may be said that CCC is deeply related with temperature of melting point. In other words, metal of higher melting point will have higher CCC.

To back up above way of thinking, following analysis in next page has been made:

Table 2-1 Comparison Physical Properties of Rhodium and Iridium

Material	c Specific Heat (J/gK)	m Density (g/cm3)	C=cm Heat Capacity (J/K・cm3)	Tm Melting Temperature (℃)	R: Resistivity μΩ・cm
1 Rhodium	0.242	12.41	3.00	1,964	No big difference See Table 2-2
2 Iridium	0.130	22.42	2.915	2,446	

Table 2-2 Comparison Resistivity（μΩ・cm）of Rhodium and Iridium

Temperature (℃)	-195℃	0℃	100℃	300℃	700℃	1200℃
Rhodium	0.46	4.3	6.2	10.2	20	33
Iridium	0.9	4.7	6.8	10.8	22	33.5

Calorie Q=R x I^2 x t R: Resistivity, I; Current, t: time

Q=C x ⊿T = C(Tm-Tr) Tm: Melting Temperature, Tr: Room temperature=25℃

Current I =SQR(Q/(R･t)), I_1=CCC of Rhodium, I_2=CCC of Iridium

(I_2/I_1) =SQR(C_2/C_1 x (Tm_2-Tr)/(Tm_1-Tr)) = SQR(2.915/3.00 x (2446-25)/(1964-25))=1.101

That is to say, if the probe temperature at CCC Limit is close to the melting point temperature, CCC will increase about 10% by changing probe material to Iridium from Rhodium.