Subject: Re: [EXTERNAL] Thermal leak of Au layer

Date: Tuesday, January 24, 2023 at 3:42:37 PM Central Standard Time

From: Lewis, Rupert M.

To: Qiang Huang, Lavin, Judith, Tsui, Lok-Kun

Attachments: image001.png

Hi Qiang,

That sounds very reasonable. Of course, if the cable were 10 um wide, that would drop the thermal leak by a factor of 100!

Cheers, Rupert

From: Qiang Huang <qhuang@eng.ua.edu>
Date: Tuesday, January 24, 2023 at 1:53 PM
To: "Lavin, Judith" <jlavin@sandia.gov>, "Tsui, Lok-Kun" <ltsui@sandia.gov>, Rupert Lewis <rmlewi@sandia.gov>
Subject: [EXTERNAL] Thermal leak of Au layer

Hi, all,

Just to follow up on what Rupert suggested yesterday, below is a quick estimate of the thermal leak of the Au layer between 800 mK and 100 mK (if the cable will go across two different temperatures).

The estimate is about 2 micro-watts, for a 10 cm long, 1 mm wide, 1 micron thick Au. It seems to be aligned with what Rupert said yesterday (a few micro-watts)?

Thanks, Qiang

The thermal conductivity (k) of gold at room temperature is 300 W/(m K), or 3 W/(cm K).

This k is a function of temperature. It also strongly depends on the impurities. I put a graph on the right from a paper.

There will be a temperature range where k is much higher, but at 1 K, as shown in the inset, this conductivity should be no more than 3 W/(cm K).

The length of the line will be about 10 to 20 cm, and the width probably depend on the design rule based on the cross talking / frequency / Q-factor...

A quick estimation : if the line is w=1 mm wide, L=10 cm long, and t= 1 micron thick, the thermal leak between 800 and 100 mK will be



$$P = k \frac{w t}{L} \cdot \Delta T = 300 \cdot \frac{1 \times 10^{-3} \times 1 \times 10^{-6}}{0.1} \cdot 0.7 = 2.1 \times 10^{-6} W$$

This 2  $\mu$ W seems to be aligned with what Rupert said yesterday (a few micro-watts)? The assumption that the temperature difference is across the entire length might not be true, causing an underestimate here. But I guess the width of 1 mm is probably much higher than the actual width. Right now the Au we used in LDRD explorer was about 2 micron, but I think 1 micron should not be a problem.

TEMPERATURE (\*K)

ŝ	Au: A=2	. ;	9.9 % 9.4 %	purity (unannealed) purity (annealed)	)
4	Au 3 Au 4 Au 4		M 3226 M 3226 M 3226	(treshiy crown) (cnnealed) (cnnealed) — 2n1	RIN
•	As S		M 3225	(redrawn)	
Fig.	2. Tł	erm	al co	nductivity of	gold.

White, G. K. "The thermal conductivity of gold at low temperatures." *Proceedings of the Physical Society. Section A* 66.6 (1953): 559.