Coulomb Blockade Thermometer (CBT) sensors for primary thermometry

Coulomb Blockade thermometer (CBT) is a primary thermometer in temperature range between 20 mK and 30 K based on change of electric conductance of tunnel junction arrays. In CBT, the differential conductance of tunnel junction array is a bell-shaped curve (Figure 1). It has been shown [1], that the full-width of the curve depends only on the (electron) temperature of the sensor and on some constants of nature.

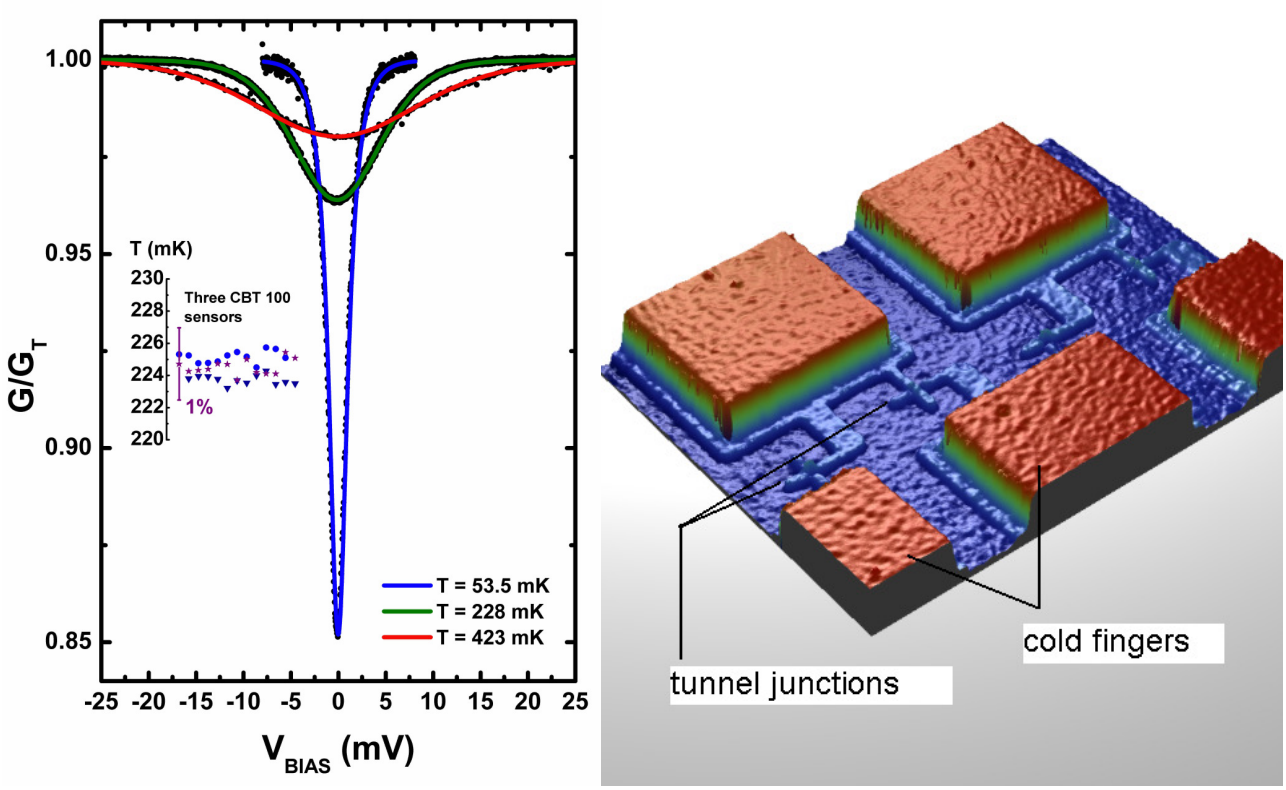


Figure 1: Left panel: Differential conductance as a function of bias voltage of CBT sensor measured at three different temperatures. G_T^{-1}=47600 Ohm. Solid line is a fit to theoretical formula [1] with two parameters. The full-width at half maximum FWHM depends only on temperature T. The depth of the conductance dip depends on temperature T and charging energy Ec, which can be calculated once T is known from FWHM. Small insert shows readings of three different sensors measured taken from several subsequent measurements. Right panel: Pseudo-color image of CBT tunnel junction array.

Coulomb blockade thermometers offer several advantages:

- **simple resistance measurement using two or four wires**
- **primary measurement mode does not need calibration**
- **fast zero-bias resistance measurement mode using e.g. standard lock-in amplifier**
- **tolerates high magnetic fields (up to 27 T, ref. [2])**

[1] J. Pekola et al, Physical Review Letters, 73, 2903 (1994)
[2] J. Pekola et al, J. of Low Temp. Phys., 128, 263 (2002)

A Finnish high-tech company Aivon Oy is committed in commercializing and further developing of CBT sensors. At the moment, Aivon offers CBT chip C1 designed for primary thermometry in temperature range 40 mK – 1 K. At lower temperatures, the self-heating of the present sensor starts to affect on electron temperature causing uncertainty to the temperature measurement and finally making the measurement unreliable below 10 mK. At temperatures higher than 1 K, almost flat conductance curve decreases the sensitivity of the temperature measurement. At higher than 40 K temperatures it is possible to trace the temperature by calibrating the zero-bias resistance versus temperature.

The following figure 2 shows the sensor type H1L2 with protective lid opened. The sensor is mounted to cryostat using e.g. varnish. For screw mounting a holder H2 is available. The lid L2 houses a strong permanent magnet to suppress superconductivity of Al-based sensor below 1K. For measurements at high magnetic fields, the magnet is not obligatory. See Table I for available options and pricing.

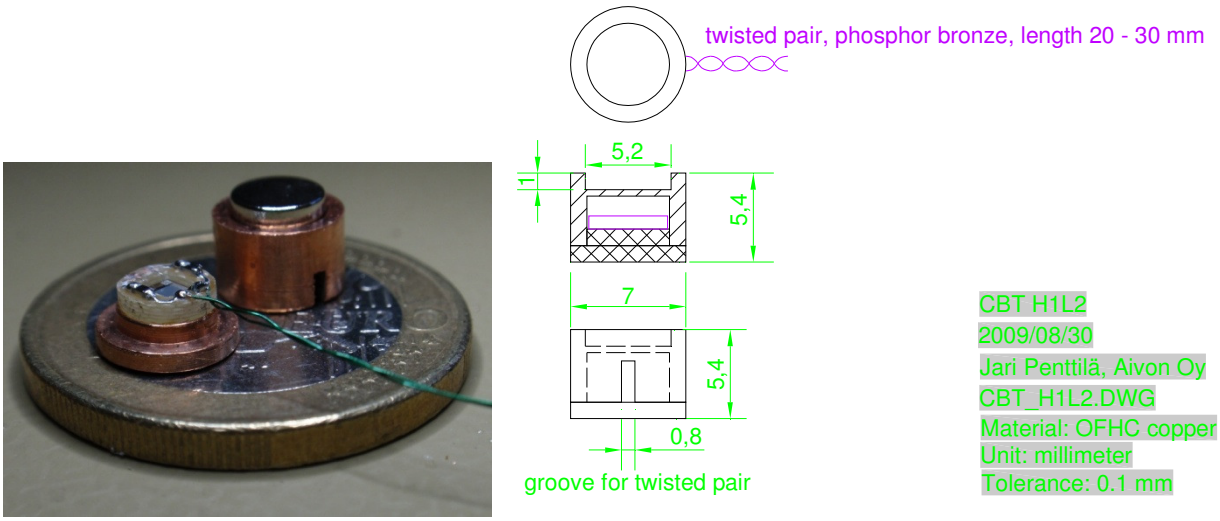
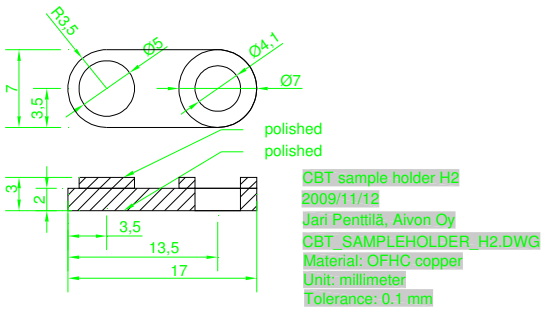


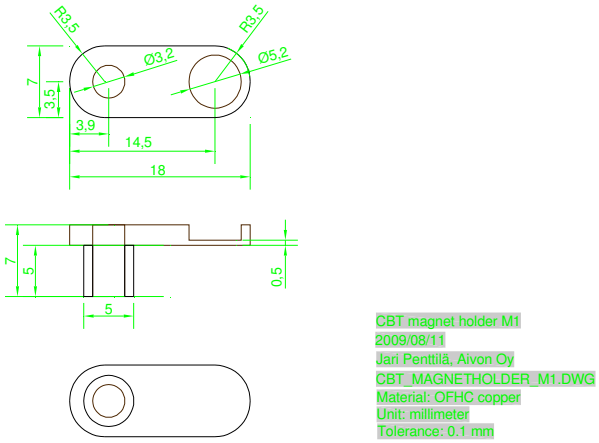
Figure 2: Left: Uncovered CBT sensor (holder/lid type H1L2) on top of 1 Euro coin. Strong permanent magnet is glued on top of the lid. Right: Dimensional drawing of the sensor.

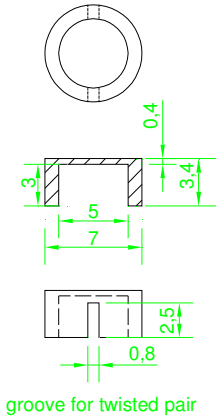
Chip C1: 40mK < T < 1K	Lid type L1	Lid type L2 (incl. magnet)	Lid L1 and magnet holder M1 (incl. magnet)
Holder H1	Yes	Yes	O
Holder H2	Yes	Yes	O

Table I: Options and availability for different sensor packages. Yes = readily available, O = available within 1 month from order.

Four prototype sensors have undergone harsh test procedure with over 300 dips between liquid nitrogen and room temperature to see whether the chip tolerates repetitive cool-downs without degradation. The resistance of the chips was unchanged. Test report available upon request.







Please do not hesitate to contact Aivon if you find CBT sensors interesting. We will gladly provide you with more information, custom-made sample holders and more specified quotations.

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