Theromocoaxial Cables as a Low Temperature High Frequency Filter

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Like compact powder filters, the thermocoaxial cables rely on the high frequency losses due to skin effect damping. They are highly resistive cables normally used as flexible heating lines in microelectronics instruments, vacuums, etc. The central wire, which is packed with MgO powder, is made of NiCr (80/20 alloy) with a room temperature resistivity $\rho_w = 1.08\mu\Omega \cdot m$ (resistance of approximately 50Ω/m at $T = 300K$). A 304L (which is more soft than the industrial strength 316) stainless steel outer conductor of outer diameter of 0.50 mm and inner diameter 0.35mm is used with a resistance of approximately $6.9\Omega/m$. It should be noted that these cables are extremely difficult to make and are equally difficult to solder.

The cables can be found at http://www.thermocoax.com. The manufacturer (Philips) is located around Europe with France and Germany being the main sources. The North American contact is

THERMOCOAX Inc.  
6825 Shiloh Rd, East, Ste. B7  
ALPHARETTA, GA 30005  
Phone : +1 (678) 947 5510  
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Email: info@thermocoax.com

Prices for a single inner wire coaxial cable is $9.57 per foot. They also make a thinner cable of outer diameter of 0.25 mm for $23.19 per foot as well as multiple inner conductor cables. In theory, the thinner cables should offer even better high frequency attenuation.

Our uses for the thermocoaxial cables are as connections from compact powder filters to the chip holders for our samples. One end of the thermocoaxial cables are fitted with a gold plated SMA plug (Amphenol spec part 901-9201-2A) and the other is connected to a copper wire which is crimped to a thin copper wire soldered directly to a 16-pin universal chip holder. In order to prevent air moisture leakage and mechanical separation from the inner and outer conductors, the wires must be sealed with epoxy as MgO tends to absorb moisture causing a short between the inner conductor and outer stainless steel sheath. This short is on the order 5 – 400 megaohms and will completely freeze out at low temperatures. Liquid Nitrogen temperatures (77K) are more than sufficient to reduce these leaks. Such a short will make measurements of samples in the kiloohm range roughly 0.01 – 1 percent accurate – low temperature measurements are of course unaffected when the leakage is zero.

The inner NiCr wire and outside stainless steel sheath is very difficult to solder as it does not wet with solder. 36 gauge copper wire with hard enamel insulation is attached to NiCr by a thin stainless steel tube (Small Parts Inc. 0.30” thin wall stainless steel tubing) by forming a crimp connection. The SMA connector end of the cable requires a custom made collar to fit the thinner thermocoaxial wires. We machine 0.1” long, 0.07” outer diameter copper tubes from a 0.125 stock piece of OFHC copper tube. The inner diameter is drilled with a number 67 drill giving enough clearance for soldering to the stainless steel sheath. In order to obtain a good solder connection, we apply acid flux on the outer stainless steel of the thermocoaxial cables with solder to wet it. It is then cleaned with water and isopropanol. The flux should be completely removed as it is highly conductive and is not normally used in electronics applications.

The process of making the wires is rather lengthy taking several minutes per lead. It involves first lightly scoring the end of the wire approximately 0.50” from the end using an Exacto knife and then using flat surface pliers to bend back and forth the outer conductor. Due to the thin wall, the outer stainless steel sheath will break easily if scored correctly. The broken piece is then squeezed several times with the flat pliers to loosen the powder inside. Once the powder has been sufficiently loosened the cut outer conductor can be pulled off to reveal the inner NiCr wire. The wire is then visually inspected under a light observable microscope at 7X magnification to ensure that the inner wire is isolated from the outer conductor. The end of the wire is then annealed approximately 2 inches from the end using a high temperature heat gun for 20-30 seconds. It is then immediately dipped into Stycast 1266 which is mixed in a 1:3 ratio by volume. The epoxy curing time is expedited by applying heat from the heat gun, taking about 15-25 seconds to fully cure. The final step is to check the connections using a high resistance testing voltmeter. We tested overload on a 2000 MΩ voltmeter on most of the wires.
Our preliminary testing results show a slightly lower cutoff frequency using an Agilent spectrum analyzer with a 2 m long piece compared to our compact powder filters. Used in conjunction with the compact powder filters, silver paste LC filters, and room temperature 1.9 MHz low frequency cut off filters (Minicircuits part number BLP1.9), we expect extremely low noise measurements are possible.

Thermocoaxial cables are expected to achieve greater than 40 dB attenuation at 100 MHz and greater than 120 dB at frequencies higher than 1 GHz.

A picture of one of our thermocoaxial connectors fitted with a male SMA connector is shown as an example. Also shown is the installation process of our thermocoaxial connectors with stainless steel compact powder filters (copper tubes) used in a dipstick setup reaching temperatures down to 1.4 K.

References

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