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CVD Diamond Thermal Conductivity

Exploration of alternate cooling method. Idea is to use a diamond plate with beryllium wedges with cooling only at the edge of the plate. (Dave Christian in 4 March talk) Looked then like a long shot as ΔT was large (27°C for 0.6% χ_0, 10°C for 1.3% χ_0, I checked these in a linear model and got rough agreement), but only had estimate of diamond thermal conductivity (1000 W/m^2−°C) from Diamonex.

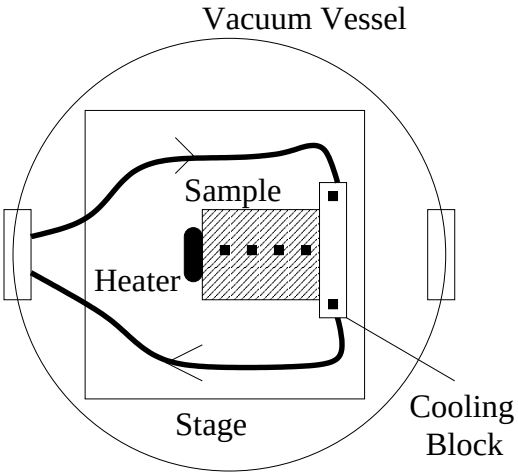
Fermilab bought some diamond plates (6.0x5.5x0.057 cm, not particularly flat) from Diamonex and at Wayne State we built a test stand to measure the thermal conductivity.

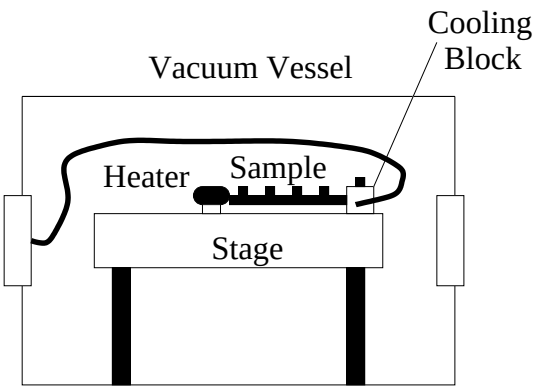
Thermal Conductivity Test Stand

Started with a disused vapor deposition system. It had 10 electrical feedthroughs and a coolant flow into a large vacuum chamber. Many other vacuum ports, 8 total, 4 of which removed (chamber splits into three vertical parts, one is a dome, second is 4 ports, and third is bottom with 4 ports), 2 blanked off, 1 for cooling, and 1 for electrical. Vacuum provided by a roughing pump and gets to a few militorr.

Added a low thermal conductivity ceramic stage (awful stuff, claimed to be machinable, but similar to chalk, very brittle). Cooling line routed to a cooling block that sits on the stage. Sample has its thin side attached to cooling block by thermal epoxy. Across the long side on the other thin side side a heater (disassembled soldering iron) is attached by thermal epoxy. Heater rests on ceramic spacers that are on the stage. Use a precision power supply for the heater (2-10 Watts, with less precise stuff could easily supply more power, feedthroughs are not high power).

Thermal sensors arranged across the long side of the sample. Sensors have three pins (common ground, common 5V power, sense line). Had 4 across these samples and two on cooling lines (in and out, never enough ΔT on these to measure a heat out).





Did test runs on Aluminium and Copper samples with similar geometry to the diamond plates to test and debug the apparatus.

Material	Thermal Conductivity ($W/m^2-^\circ C$) Measured	Expected
aluminum	190	200
copper	420	390
diamond	850	1000?

Scatter in the measures (6/sample/run) are typically 20%, with systematically higher conductivities (lower ΔT) as the pairs get closer to the cooling block. Repeated runs and power variations (not yet for diamond) scatter by 10%

Conclusion

Diamond plates with cooling on the edges are not a viable option for cooling pixel detector modules. ΔT too high for a reasonable amount of material.