

## ***Closed Cycle Cryocoolers in Low Temperature Silicon Analysis***

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Sensitive analysis of solar grade silicon material requires sample cooling to very low temperature. Closed cycle cooling that requires no cryogenic liquids allows very low detection limits to be achieved. Quantification of group III and V shallow impurities in single silicon crystal down to the low ppta range, substitutional carbon in polysilicon or single crystal silicon down to the low ppba range and also of interstitial oxygen in polysilicon or single crystal silicon down to the low ppba range is made possible by application of closed cycle cryo cooling. Very low detection limits are achievable. For single crystal material at liquid helium temperatures, detection limits as low as parts per trillion atoms (ppta 10<sup>-12</sup>) can be achieved for some impurities. Combination of a high performance FTIR interferometer with closed cycle cryo cooling that does not require any liquid nitrogen or liquid helium has enabled low temperature impurity analysis and quality control of solar grade silicon crystals that conforms to international ASTM/SEMI standards. The closed cycle cryo cooling technology frees from the need to use expensive and potentially hazardous cryogenic liquids. Solar power is a smart way to reduce carbon emissions. (advise an emphasis on closed vs. open cycle cooling OR CEC)