Properties and Processes for Cryogenic Refrigeration

The NIST research described here addresses measurement and process issues associated with cryogenic refrigerators, i.e. cryocoolers, and materials performance that are limiting growth in a wide array of technology areas from sensors to liquefaction of industrial gas. Proper measurements need to be established to characterize losses within cryocoolers and models need to be developed to optimize the design of such systems. Material properties at cryogenic temperatures also are needed by industry for the design of cryogenic equipment, but the data are difficult to find and interpret.

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Cryogenic temperatures are required for many technology areas, including infrared sensors for surveillance and atmospheric studies; superconducting electronics, magnets, and power systems; to create clean vacuums in semiconductor fabrication processes; for liquefaction of industrial gas, and many other existing and potential applications.

In the data and methodology area, the layout of our web site has been redesigned to provide clear access to references for the database on cryogenic material properties and to add a graph of each property as a function of temperature between about 4 K and 300 K. The web site is in the process of being updated with many of the graphs being added to materials already on the web site. We will continue adding new information. An invited paper on our Cryogenic Materials Property Database was presented at the International Cryogenic Materials Conference in Prague in June by Peter Bradley. Two invited short courses on cryocoolers were presented by Ray Radebaugh this year. The first was a one-day course given on June 13, the day before the International Cryocooler Conference, in Annapolis, MD. The second was a half-day short course emphasizing superconducting applications and was given the day before the Applied Superconductivity Conference in August.

Measurements of the resonance effect in inertance tubes used for phase shifting between flow and pressure in pulse tube refrigerators were carried out this year and reported on at the International Cryocooler Conference in June by Mike Lewis. The real and imaginary parts of the impedance were measured for frequencies from 40 to 70 Hz. The results agreed fairly well with our model predictions, although they begin to diverge at the highest frequency of 70 Hz. Further measurements at high frequencies are therefore warranted at this time. This resonance effect can be utilized to provide for a faster cool down time of pulse tube refrigerators.

In January the research team was notified that it received the first DARPA contract as part of their new MEMS program on Micro Cryogenic Coolers (MCC).

The first phase is 18 months and the second phase is 18 months. The University of Colorado is the prime contractor in this program and the NIST Electromagnetic Division is also collaborating on this program.

The goal of the program is to cool a high-T_c superconducting terahertz detector to 77 K with 3 mW of cooling and have the entire system occupy less than 4 cm^3.

This year we have identified a few optimized refrigerant mixtures in collaboration with Marcia Huber of the Theory and Modeling of Fluids Group to use in the Joule-Thomson cryocooler. The use of glass microchannel plates with square pores of 20 μm on a side is planned for the heat exchanger. The University of Colorado is currently testing various manifolding techniques for the heat exchanger.

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