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Low Temperature Emissivity Measurement System

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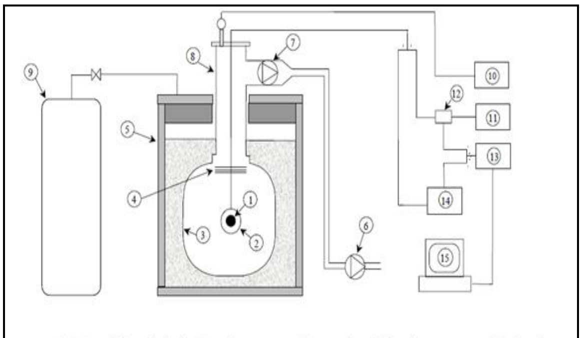
Abstract
The emissivity of a material is the relative ability of its surface to emit energy by radiation. It is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature. Knowledge about the low temperature emissivity of materials and coatings can be essential to the design of fusion cryoplants and in the thermal modeling for space satellite missions. The emittance of materials at cryogenics temperatures often cannot be predicted from room temperature data, but for computing radiative loads and infrared backgrounds this cryogenic data is often required. Measurement of the cryogenic emissivity of a highly reflective surface is a significant challenge: little thermal power is radiated from the sample, and the background radiation. However some researchers have measured emissivity at various low temperature ranges. Present work reports, the various emissivity measurement setup and their considerations.
Keywords*:* Emissivity, Cryogenics

I. INTRODUCTION

Every surface at a temperature above 0 K emits thermal energy in the form of electromagnetic waves, which is termed thermal radiation. Emissivity is the ratio of energy emitted by a surface to the theoretical limit (blackbody radiation) at the same temperature. Absorptivity is the fraction of incident radiation which is absorbed by a surface. Reflectivity and transmissivity are the fractions of incident radiation reflected and transmitted through the surface, respectively. The absorptivity, reflectivity, and transmissivity of a surface must total 1. Thus, the reflectivity and absorptivity are related, and for opaque surfaces (zero transmissivity); the energy received and emitted by radiation is governed entirely by the emissivity and the absorptivity of the surface. Thus, to keep the temperature of a satellite at an operational level, careful design of the outer surfaces with respect to absorptivity and emissivity is critical [1]. Moreover, accurate measurement of these properties is necessary to assess new materials and structures for satellite thermal control and also for selection of coatings on cryosurface in large scale cryopump is also very important. Material data on radiative properties like total hemispherical absorptivity and emissivity of thermal radiation is important for the minimization of parasitic heat flows in cryogenic devices. Dispersion and lack of published values of these radiative properties lies probably in their sensitivity to surface treatment and the difficulty of measurement, especially at low temperatures.[2] For application in cryogenics, knowledge of optical properties of materials at low temperatures and in the far infrared spectral region is required.

II. EMISSIVITY MEASUREMENT APPARATUS

Hameury et al., In their research paper "measurement of total hemispherical emissivity using a calorimetric technique" in 2005 they had design apparatus and built at LNE (Laboratoire National de Métrologie et d'Essais) for measuring the total hemispherical emissivity of solid materials in the temperature range 253 K to 473 K; Figure 1 shows a general diagram of the apparatus. The heater, used to heat two identical samples surrounded by a thermal guard, is suspended at middle height of a black vacuum power supplied to the samples and the measurements of the temperatures in the samples and in the thermal guards. A Eurotherm controller controls the temperatures of the samples heater and of the thermal guard. Chamber thermo stated with boiling nitrogen.



LNE total hemispherical emissometer : (1) sample; (2) heating system; (3) chamber; ; (4) radiative screens; (5) dewar; (6) valve vacuum pump; (7) turbomolecular vacuum pump, (8) access well; (9) nitrogen tank; (10) manometer; (11) electrical supply; (12) calibrated shunt resistor; (13) voltmeter; (14) 0°C reference for thermocouples; (15) computer.

Figure 1 LNE total hemispherical emissometer [J Hameury et al. (2005)]

A PC computer controls the measurements of the electrical. The total hemispherical emissivity is computed from the net heat-transfer rate of the circular surfaces of the samples. The model is built up using the "radiosity method", that is to say considering that the emission of the surfaces is Lambertian, the reflection on the surfaces is perfectly diffuse and the spectral emissivities of the surfaces are independent of wavelengths.

V. Musilova et al., in their research paper "Low temperature radiative properties of materials used in cryogenics", in 2005

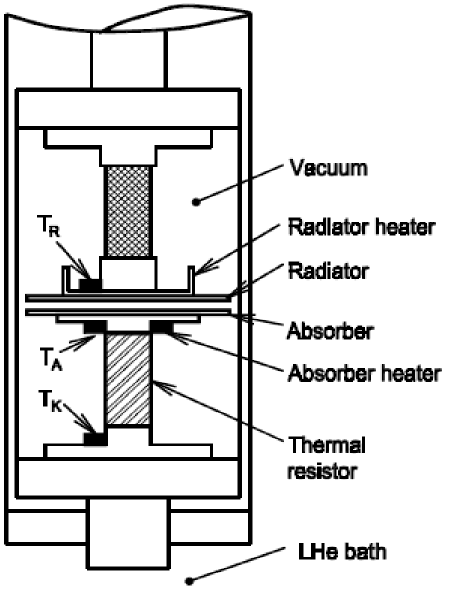


Figure 2 Schematic diagrams of apparatus to measure emissivity [J Hameury et al. (2005)]

Total hemispherical absorptivity is measured, when the sample is cold and irradiated with heat emitted by the heated black surface. On the contrary, the sample is heated and the black surface is cold during total hemispherical emissivity measurements in the temperature range 4 K to 140 K; Figure 2 shows a general diagram of the apparatus. Both absorptivity and emissivity are evaluated as a ratio between the transferred heat and heat emitted by a black body surface heated to the temperature and having an area equal to that of the sample. An electrical heater attached to the radiator sets the temperature to values ranging from 30 K to about 140 K. When the radiator is heated, the absorber temperature varies from 5 to 15 K.

R. C. Duckworth et al. in their research paper "Measurement of the Emissivity of Clean and Contaminated Silver Plated Copper Surfaces at Cryogenic Temperatures", in 2006 through the use of a single-stage cryocooler, a flexible experiment has been constructed to measure the emissivity as a function of temperature between 25 K and 35 K. Measurements of a series of silver-plated copper plate samples that are compared to previous data at room temperature and 77 K.

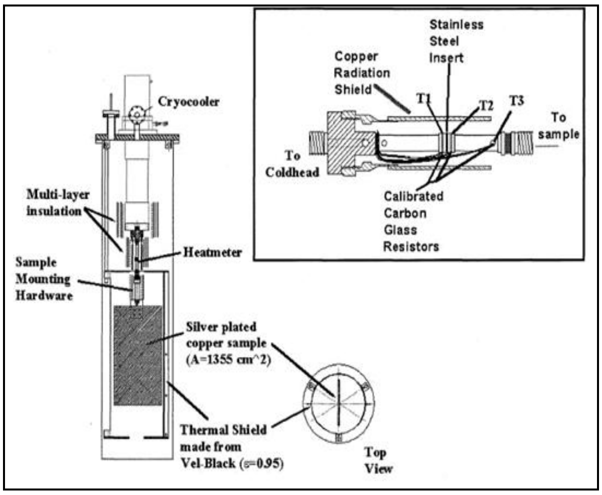


Figure 3 Diagram of emissivity measurement test facility [R. C. Duckworth et al. (2006)]

The emissivity for a given sample is found through the measurement of the radiant heat transfer between the thermal shield and the test sample as shown in Figure 3 the sample is secured to a single stage Cryomech AL330 cryocooler through a "heatmeter" and the sample is enclosed within an aluminum shield that has been covered with a Vel-Black® applique. This aluminum shield serves as the blackbody radiation source with the calibration completed, the sample plate was then inserted into the test setup, the system was pumped down to a vacuum of 2 x 10^{-5} Torr, and the cryocooler operated until a thermal equilibrium was established. The temperature of the sample was measured directly above the sample on the bottom of the sample mounting hardware. From the calibration, the net increase of the heat load is then due to the sample radiation exchange with the warm blackbody environment. The emissivity of the surface can be found from the expression for the radiation exchange between two enclosed surfaces.

P. Herve et al. in their research work "Direct measurement of total emissivities at cryogenic temperatures: application to satellite coatings", (2008) they had develop an emissivity measurement under supervision of ALCATEL SPACE (Planck prime contractor); to study the emissivity of different coatings in the temperature range 40–200 K. In order to make total emissivity measurements for coatings, the sample holder (Figure 4) is a cylinder directly linked through a rod to the second stage of the helium refrigerator.

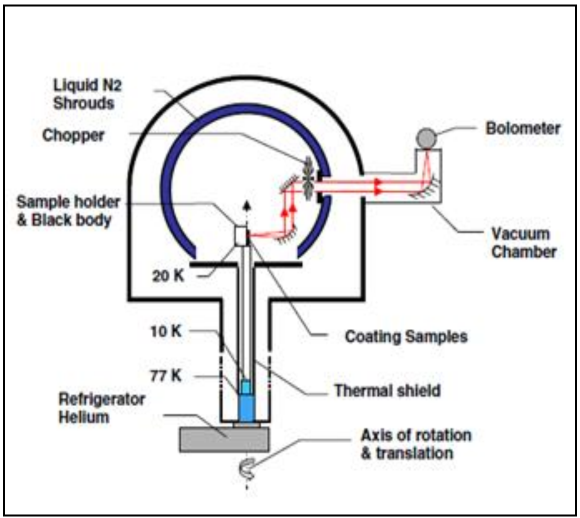


Figure 4 Schematic of the experimental [P. Herve et al. (2008)]

For each measurement, five different samples can be disposed on the holder. A blackbody, with its aperture disposed on the optical path of the measurement setup, is positioned at the top of the sample holder. The whole system can be rotated and translated along its axis to allow measuring of the emission of each sample at multiple angles

III. CONCLUSION

To measure the emissivity at low temperature three different methods were used which in first method radiative heat transfer model approach is used as presented in the research paper which is based on calorimetric emissivity measurement principal and to measure the emissivity at very low temperature low temperature achieved using the liquid cryogen or using the cryocooler. In second method emissivity is measured using the by measurement of the reflectivity ρ, knowing the relationship $\varepsilon = 1 - \rho$. The third method reported by researcher is direct measurement of emissivity ε using the bolometer to sense the direct radiation coming from the sample surfaces.

REFERENCES

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