INFRARED SPECTROMETER ACCESSORIES

Analysis of the Thermal Runaway Properties of Germanium using the Variable Temperature Cell Holder

Introduction

The suitability of an infrared material for a particular application is assessed on a number of characteristics, such as: consideration of the useful wavelength transmission range, extent of surface reflection losses, inertness, thermal conductivity, thermal expansion coefficient, hardness, and susceptibility to thermal and mechanical shock.

Germanium (Ge) is a very versatile optical material used in thermal imaging systems, optical design applications, and infrared analysis. It is non-hygroscopic, chemically resistant to many solvents, has an excellent surface hardness, and good mechanical strength. It also has a wide optical transmission range from 2 to 12 microns. Though it does have high reflection losses due to its high refractive index, these may be greatly reduced by employing an appropriate anti-reflection coating. Its high refractive index makes it a material of significant interest for use in infrared attenuated total reflection (ATR) optical spectroscopy.

Figure 1: The Specac Variable Temperature Cell Holder

Experiment

The transmission of some infrared materials is known to reduce with temperature, and Ge a

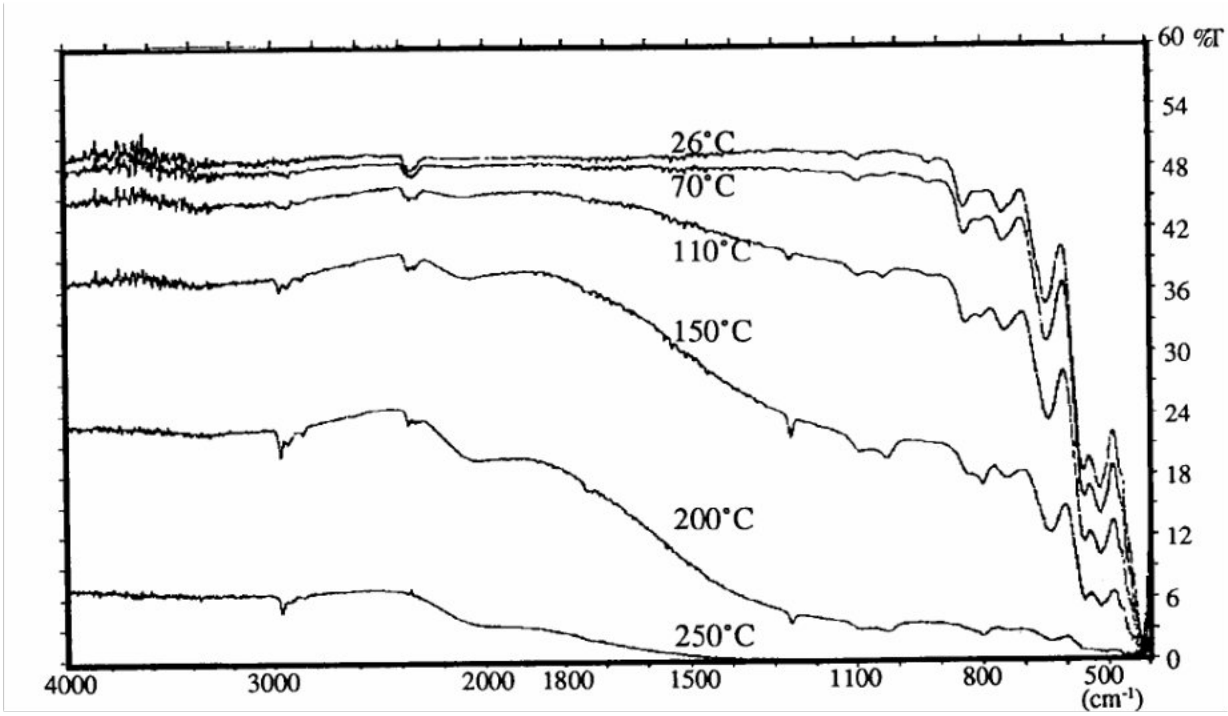

Figure 2: Plot of optical transmission versus wavenumber (cm^{-1}) at different temperatures

material known to exhibit such thermal runaway properties. Consequently, it is important to know the relationship between transmission and temperature in applications involving Ge optical components.

This application note describes an experiment in which the Specac Variable Temperature Cell Holder (21525), as shown in Fig. 1, was used to study optical transmission as a function of temperature for a Ge sample. The Variable Temperature Cell Holder has a temperature range from -190°C and +250°C, and has been designed to give high precision variable temperature performance in routine or research applications. This accessory may be installed in most FTIR spectrometers without need for alignment. It may be used for both solid and liquid sample analysis, in conjunction with an appropriate Specac solid or liquid sample cell*. For this work, the Ge sample was held within the Variable Temperature Cell Holder in the Specac Advanced Solid Transmission Cell (20610).

Results and Discussion

The spectra shown in Fig. 2 were recorded on a FTIR spectrometer set to 8cm^{-1} resolution and 8 scan averages. A mono-crystalline n-type Ge disk (2mm thick, and 5-40 ohm.cm resistivity) was used as the sample which had its temperature varied from ambient to +250°C.

These results clearly demonstrate that the thermal runaway properties of Ge become appreciable at about 150°C. This effect is due to the generation of free electrons at elevated temperatures, with a proportional increase in

* Note that the sample cell may have a temperature range different to that of the Variable Temperature Cell Holder.

free electron absorption. N-type and/or low resistivity Ge, is known to exhibit slightly less thermal runaway than the p-type and/or high resistivity Ge. The bands observed beyond 860cm^{-1} (11.7 µm) are due to overtones of the fundamental phonon absorptions and have been shown in scientific literature to be independent of carrier concentration.

Conclusion

For heated spectroscopic applications such as monitoring heated process flow streams by ATR or heated gas analysis, Ge is a suitable material only up to 150°C for wavelengths beyond 11 microns. Above this temperature the transmission reduces significantly, and Ge may not be appropriate for infrared transmission studies.

The total transmission range is reduced with increased temperature, with a 2 mm thick sample becoming completely opaque above 7 µm (1430 cm-1) at 250°C.

This study confirms why Ge is restricted to low power CO_2 laser applications (typically 100 watts cw), and is not used as an aerodynamic transmitting component where heat is likely to be generated.

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