Simple cryogenic infrared window

M. Hartemink and H. P. Godfried

Nederlands Centrum voor Laser Research B.V., Postbus 2662, 7500 CR Enschede, The Netherlands

(Received 20 November 1990; accepted for publication 5 December 1990)

A simple, cheap technique is reported that allows materials with both large and small thermal expansion coefficients to be mounted as windows in low temperature cryostats while at the same time avoiding thermal stresses. The construction may be thermally cycled many times with no change in its properties. It can hold differential pressures of at least 1 atm for a 1-in.-diam window. This technique seems to be particularly useful for applications where the use of soft materials cannot be avoided (e.g., ZnSe in the infrared).

Materials that transmit in the medium and far infrared (beyond 8 μm) are often quite soft resulting in large thermal expansion coefficients. As a consequence, mounting these materials in a cryogenic environment can easily result in thermal stress, possibly even breakage, due to the large difference in thermal expansion coefficients with conventional materials such as glass or metals. We report here on a simple technique that will allow such windows to be cooled down to 77 K with very low thermal stress. As an example mounting of a ZnSe window onto glass is treated. However, this technique is not limited to ZnSe on glass. Other materials that could be used as windows include NaCl, Ge, BaF₂, CaF₂, quartz, etc. We also note that this technique may be useful to reduce mounting induced birefringence in optical windows.

The window construction is shown in Fig. 1. A 1-in.-diam 3-mm-thickness ZnSe window was epoxied to a kapton foil (130 μm thickness) in which a 20-mm-diam circular hole had been punched. Centering of the window with respect to the hole was done with teflon or PVC alignment jigs that also applied some mild force to obtain a thin layer of epoxy. We used Stycast 1266 two component epoxy from Emerson and Cuming¹ from which air bubbles had been removed by vacuum pumping for about 5 min. To lower its viscosity and improve adhesion this was heated to approximately 60 °C while curing. The kapton foil was subsequently epoxied onto a pyrex tube (31 mm o.d., 1.5 mm wall thickness) whose end had been ground flat. Centering was either done with an alignment jig [Fig. 1(a)] or by visual inspection [Fig. 1(b)]. After curing excessive kapton was removed with a razor blade knife. Conventional glass-metal joints could then be used to mount the window into the cryostat (Fig. 2). Alternatively the kapton foil could be mounted directly on a metal tube or flange.²

The window construction was found to easily withstand the thermal shock of repeatedly dipping in liquid N₂ from room temperature without any visible damage (cracking, chipping). After this repeated thermal shock the system still showed no signs of leakage or weakening in terms of its ability to support a pressure differential. The construction with the window facing the higher pressure side [Fig. 1(a)] was found to be able to withstand a pressure differential of at least 1 atm. Higher pressures were not applied. With the kapton foil on the high pressure side

[Fig. 1(b)] the construction failed at about 0.5 bar pressure differential because the epoxy severed from the ZnSe window. Adhesion to the kapton foil was still perfect. Possibly this was caused by a failure of the AR coating on the ZnSe window. No attempts were made to test uncoated ZnSe windows. Helium leak detection was not possible since He diffuses through kapton at room temperature. However, in a clean system pressures below 10⁻⁵ mbar were easily obtained at room temperature. This was limited by outgassing in the vacuum lines (not the window construction itself).

Using this technique the thermal stress applied to the ZnSe windows is virtually eliminated because of the elasticity of the kapton. Deformations of the window are therefore mainly gas pressure induced. Since the kapton does not in any way restrict the window motion, the deformation δ of a circular window is given by³

$$\delta = \frac{12(5 + \nu)(1 - \nu)pD^4}{(1024 Et^3)}, \quad (1)$$

with E the modulus of elasticity, ν Poisson's ratio of the material ($\nu = 0.28$ for ZnSe), D , t its diameter and thickness, respectively, and p the pressure differential.

The maximum stress in the window occurs in the center and is given by³

$$S_{\text{max}} = \frac{6(3 + \nu)pD^2}{64t^2}. \quad (2)$$

This should always be substantially lower than the apparent elastic limit.

The window construction described above was used in a setup for infrared absorption measurements in cold CF₄ gas using a cw CO₂ laser. The absorption cell is shown in Fig. 2. It consists of a 3-m-long triple walled pyrex tube whose inner wall can be cooled with liquid N₂ or the boil-off from a N₂ storage dewar for intermediate temperatures. To avoid thermal gradients in the absorbing gas the infrared radiation entered and exited through double AR coated ZnSe windows. At the room temperature side the windows were epoxied directly onto the pyrex tube again using Stycast 1266. The cold windows were mounted as shown in Fig. 1(b) facing away from the CF₄ gas. It is noted that higher pressures could be obtained by suitably

FIG. 1. Cryogenic window. (a) Window facing the atmospheric surroundings. (b) Window facing vacuum side, which may be less vulnerable.

FIG. 2. Cold cell with cryogenic window. The temperature gradient from the cold section to room temperature is avoided by the double window construction.

filling the pyrex mounting tube with some low conductivity noninfrared absorbing gas (e.g., Kr, Xe).

¹Emerson & Cuming Europe N.V., Westerlo, Belgium.

²This was not attempted but we feel this should be fairly easy to accomplish in view of previous experience of one of us (HPG) with superfluid He leaktight kapton-to-metal seals, again using Stycast 1266 epoxy. See also A. P. M. Matthey, J. T. M. Walraven, and I. F. Silvera, *Phys. Rev. Lett.* **46**, 668 (1981).

³P. Dellus, *Resistance des Materiaux, Technique et Vulgarisation*, Paris (1964).