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# Properties of CGW-7806 Glass

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# PROPERTIES OF CGW-7806 GLASS

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## ABSTRACT

Optical, physical, and chemical properties have been measured for CGW-7806 glass, which has been proposed for use in heliostats. In general, the properties of this glass are similar to those of other potential heliostat materials. Although this glass has not been commercially produced in a low-iron form, research specimens indicate that it can be made with very high optical transmission. Chemical solubility measurements indicate satisfactory durability except in very high pH solutions. This behavior is similar to that of float glasses and other potential heliostat glasses.

# PROPERTIES OF CGW-7806 GLASS

## Introduction

Current solar central receiver concepts require several hundred thousand square feet of highly reflective surface in the form of second surface glass mirrors. A variety of glasses are under consideration for this application. The optical[1] and physical[2] properties of a number of these glasses have been described in previous reports. This paper presents the results of similar measurements for another glass, CGW-7806 (a lime borosilicate to be produced by the fusion process), recently proposed for this application by Corning Glass Works, Corning, New York.

## Experimental Procedure

### Specimens

CGW-7806 is currently produced only as tubing at a plant in India. Most of the material supplied by Corning Glass Works was in the form of tubing having an outer diameter of 2.52 cm and an inner diameter of 2.32 cm. A small amount of material was supplied as plates which had been formed by flattening tubing by heating on a graphite block. This material had a flame-polished surface on one face and a rough surface on the other face. A third set of specimens were produced at Corning, New York, in a laboratory scale melt. These specimens, designated M-5-5974, were supplied as square plates, 2.5 x 2.5 x 0.6 cm. They had excellent surfaces on the two opposed large faces, but did contain a large number of bubbles.

## Physical Property Measurements

Details of the physical property measurement techniques are given elsewhere.[2] The thermal expansion coefficients were measured with a horizontal, vitreous silica dilatometer. The refractive index was measured with an ABBE Refractometer. Densities were determined by the Archimedes' Method with water as the immersion fluid.

## Optical Measurements

Absorption measurements were performed on a Cary 17-I spectrophotometer. A Cary #1413 specular-reflectance accessory, utilizing a modified Strong V-W configuration, was used for the reflectance measurements. Normally this configuration gives a signal which is proportional to the square of the sample reflectivity. However, when dealing with low reflectivities it is preferable to use a secondary reference mirror in one position in the W-configuration and obtain a signal linear in the sample reflectivity. This latter procedure was followed in this study. The accuracy of both the transmissivity and reflectivity measurements is believed to be within $\pm$ 0.01 over the entire spectral range studied.

## Chemical Durability

The effect of pH on the chemical durability of this glass was determined for the flattened tubing specimen. Specimens were placed in 250 $cm^3$ of solution of the desired pH and held for 7 days at 80°C. Acid solutions were obtained using hydrochloric acid whereas basic solutions were obtained by varying the concentration of sodium hydroxide. The specimens were weighed on an analytical balance to $\pm$ 0.0001 gm before and after exposure. Weight losses were normalized to the specimen area, which was approximately 10 $cm^2$ in every case.

## Results and Discussion

### Optical Properties

The solar weighted (air mass 2) transmissivity ($T_S$) and reflectivity ($R_S$) of the flattened CGW-7806 tubing and the special laboratory melt are given in Table I. As a result of the inferior optical quality of the flattened tube sample, the measured transmissivity and reflectivity for this sample are expected to be somewhat lower than characteristic for this composition. It is difficult to estimate the magnitude of this effect. However, it appears that the main effect of the poor surface quality is to increase the amount of diffuse scattering. In this case, one would expect a much more pronounced effect on the specular reflectivity measurements (collection angle of ~ 1°) than on the transmission measurements (collection angle of ~ 4-5°). Accordingly, in analyzing the tubing data we will use the transmissivity of the flattened tube but will assume that the reflectivity is that of the laboratory melt.

Comparison of the transmissivities is facilitated by normalizing results to a common sample thickness, e.g. that of the proposed heliostats 0.100". To do this, we note that the absorption losses (A) are small. In this case

$$A \simeq 1-T-R \qquad (1)$$

and depends linearly on the sample thickness. The extrapolated transmissivities are then 0.813 and 0.916 for the flattened tubing and the laboratory melt, respectively. The origin of this large difference in the transmissivities of the two samples may be seen in Figure 1, which shows the absorption coefficient as a function of wavelength. The $Fe^{2+}$ intra-ion band at ≃ 1.125 μm is 14.5 times more intense in the flattened tubing than in the laboratory melt. It is this difference in ferrous ion content that gives rise to the large differences in solar weighted transmissivity.

A more complete treatment of reflective losses (i.e., including wavelength dependence) and careful background subtraction yield the $Fe^{2+}$ and $Fe^{3+}$ absorption coefficients tabulated in Table II. Unfortunately, the extinction coefficients for $Fe^{2+}$ and $Fe^{3+}$ in this class of glasses, i.e., lime borosilicate, have not been determined. However, if one assumes the iron to be predominantly in the $Fe^{3+}$ state (as is common for many glasses, and as is consistent with results for $Fe^{2+}$ and $Fe^{3+}$ in a soda-silicate glass) the flattened tube sample contains ~ 3 times more iron than does the laboratory melt. This is not really surprising since the laboratory melt was probably made from reagent grade chemicals and possibly even melted in a platinum crucible. Further, one should note that the laboratory melt is in a considerably more oxidized state. This may be seen by noting that even though the $Fe^{3+}$ concentration, and hence the total iron concentration, of the flattened tube is only ~ 3 times higher than that of the laboratory melt, the $Fe^{2+}$ concentration is ~ 14 times higher. It is this combination of a higher iron concentration and a more reduced state that result in the flattened tubing having a significantly lower solar transmissivity than the laboratory melt.

## Physical Properties

Although all the physical properties of CGW-7806 glass (see Table III) differ measureably from those of float glasses and of CGW-0317 glass[2], only the thermal expansion coefficient exhibits a large enough difference to have any practical impact on heliostat design. The thermal expansion coefficient of CGW-7806 is about 70% of that of the other potential heliostat glasses. Current heliostat designs require the mirror to be bonded to a rigid substrate. The stresses which arise in the glass during thermal cycling, e.g., day to night temperature changes, will be directly proportional to the difference between the expansivity of the glass and that of the substrate. Since these stresses may lead to cracking of the glass, they should be kept to a minimum. It follows that overall heliostat design must allow some consideration for the expansivity of the candidate mirror materials.

The other physical properties of CGW-7806 also differ measurably from the glasses discussed earlier.[2] The slight decrease in the refractive index relative to float glasses does mean that the front surface reflectivity of CGW-7806 will be slightly lower than that of a float glass, but these values differ by only 0.16%, which should not be significant. The glass transformation temperature of CGW-7806 glass is about 25°C higher than that of typical float glasses, which will affect the annealing cycle used by the glass supplier, but should have no effect on heliostat performance. The density of CGW-7806 glass is slightly less than that of float glass but, since mirror weight is primarily determined by the glass thickness, this density difference should be insignificant.

Chemical Durability

The effect of pH on the weight loss of CGW-7806 glass for one week exposures is shown by the solid points in Figure 2. Similar data (open points) for PPG low iron float glass are also shown in the figure. The two glasses appear to have similar durabilities over most of the pH range studied, although CGW-7806 does appear to be somewhat more durable at pH values between 8 and 12. This may be of some practical significance since the pH of water saturated with Barstow soil is ~ 8 to 9. The specimen held at pH = 13.8 was the only specimen of CGW-7806 to exhibit significant changes in optical properties. That specimen was distinctly frosted and had a considerably decreased total solar transmission.

REFERENCES


1. J. Vitko, Jr., "Optical Studies of Second Surface Mirrors Proposed for Use in Solar Heliostats," SAND78-8228, April, 1978.
2. J. E. Shelby, "Physical Properties of Potential Heliostat Glasses," SAND78-8225, April, 1978.

TABLE I. Measured solar weighted transmissivity ($T_S$) and reflectivity ($R_S$) of available Corning 7806 samples and extrapolated transmissivities for 0.100" thick heliostat glass. (Because of the inferior optical quality of the flattened tube, all extrapolations use the measured reflectivity of the lab melt, i.e. $R_S$ = 0.074).

| Corning 7806 | t(cm) | $T_S$ | $R_S$ | $T_S$ (extrapolated to t = .254 cm) |
|---|---|---|---|---|
| Flattened tube | 0.11 | 0.877 | 0.068 | 0.813 |
| Lab melt | 0.61 | 0.902 | 0.074 | 0.916 |

TABLE II. Measured absorption coefficients for the $Fe^{3+}$ charge transfer band at 0.380 μm and the $Fe^{2+}$ intra-ion band at 1.125 μm. The absorption coefficient $\alpha$ is defined by $\alpha = 1/d \log_{10} (I_0/I)$ where $I_0$ and I refer to the intensity of the incident and transmitted beams respectively, and d is the sample thickness in cm.

| Corning 7806 | $\alpha$ ($cm^{-1}$) | |
|---|---|---|
| | 0.380 μm | 1.125 μm |
| Flattened tube | 0.030 | 0.436 |
| Lab melt | 0.0092 | 0.034 |

TABLE III

PHYSCIAL PROPERTIES OF CGW-7806 GLASS

| Form of Specimen | Expansivity* (x $10^6$/°K) | $T_g$ (°C) | $T_d$ (°C) | Index | Density (gm/$cm^3$) |
|---|---|---|---|---|---|
| Tubing | 6.08** | 573 | 624 | 1.5071 | 2.407 |
| Flattened tubing | 6.86 | 574 | 620 | 1.5075 | --- |
| Special melt | 6.74 | 574 | 616 | 1.5060 | 2.421 |

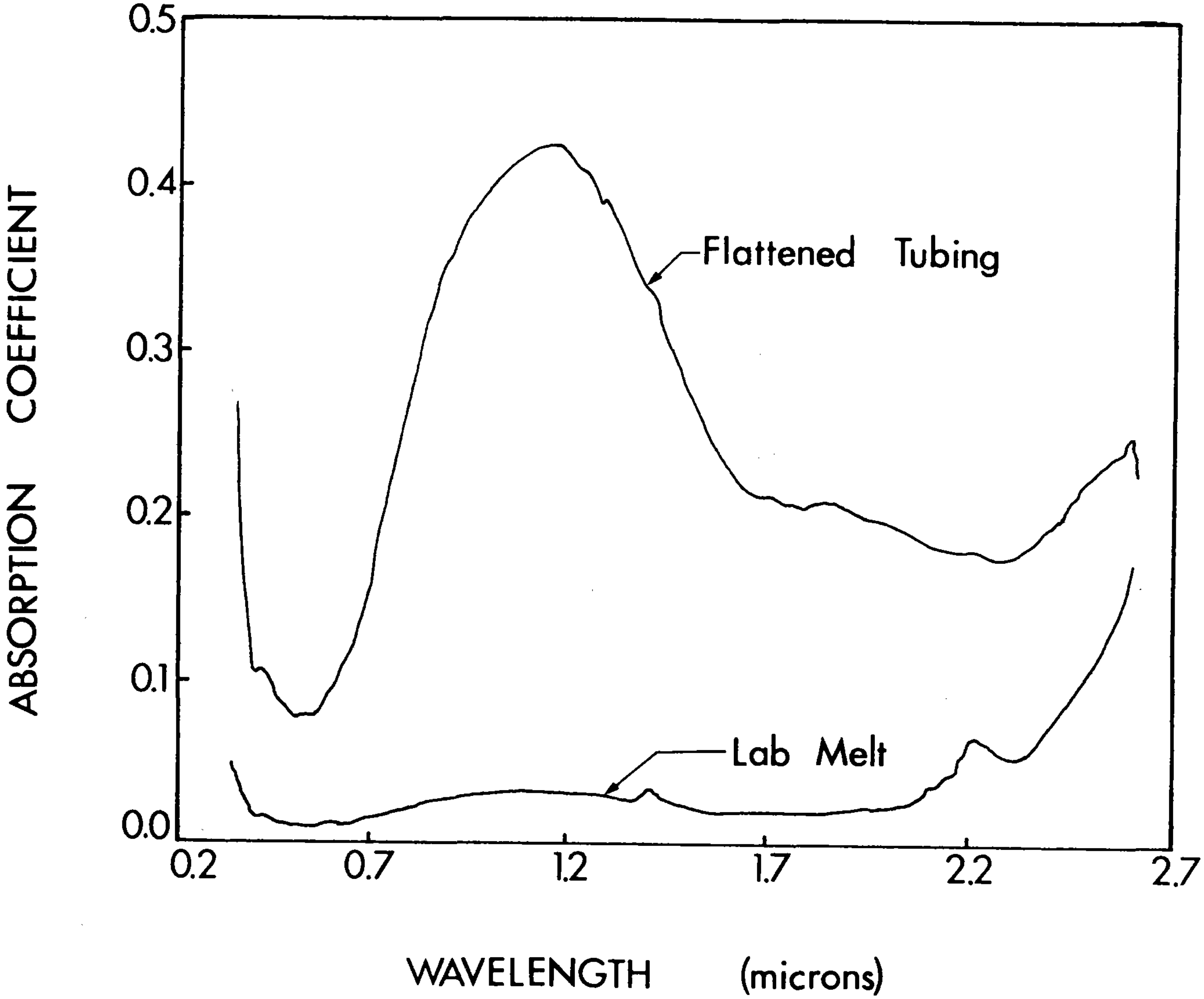
*Average expansion coefficient 25 - 300°C.

**Specimen obviously not annealed.

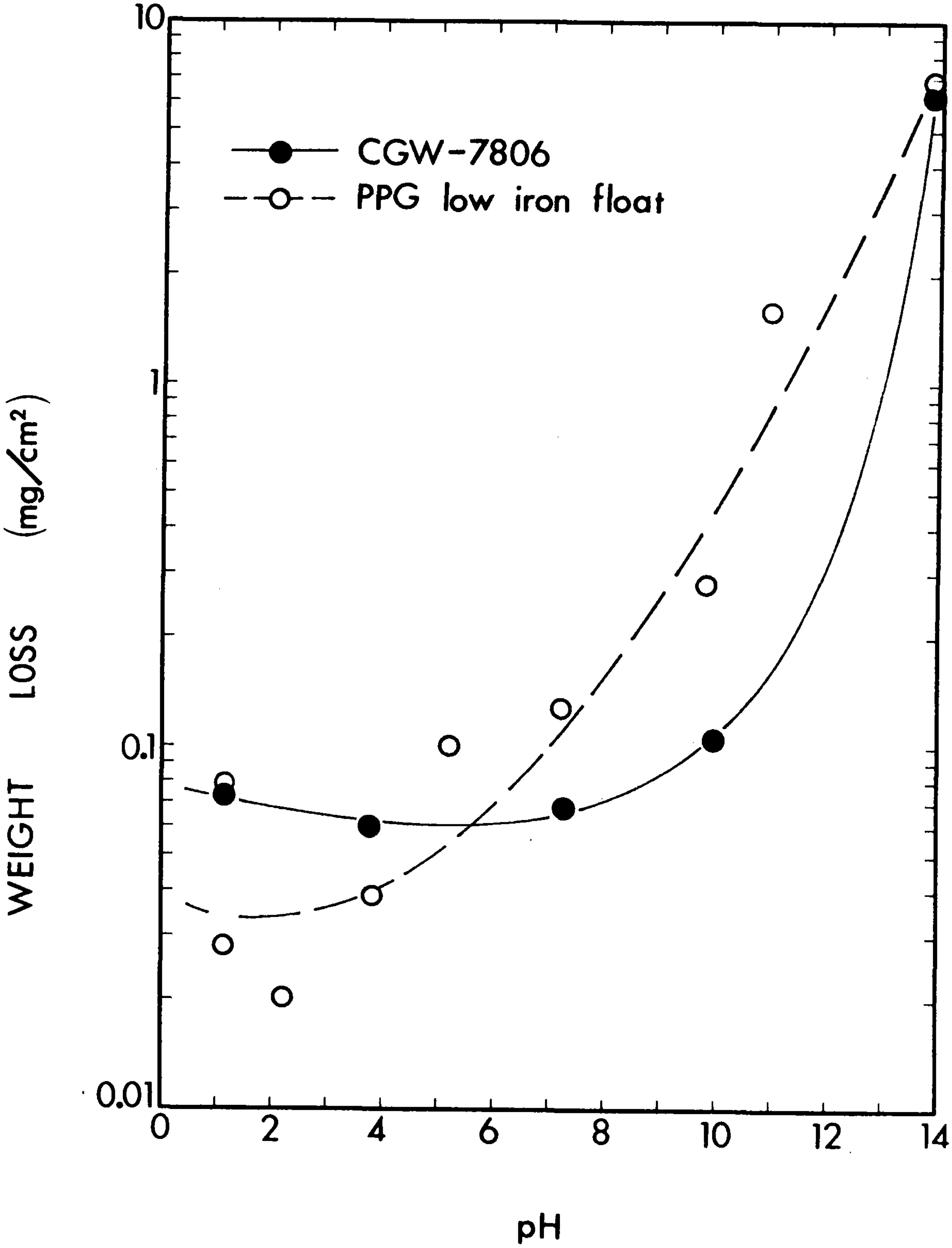
## FIGURE CAPTIONS

Figure 1: Wavelength dependence of the absorption coefficient of CGW-7806 glass for both the flattened tubing and laboratory melt specimens. (A reflectivity of 0.074 has been assumed at all wavelengths.)

Figure 2: Effect of pH on the dissolution rate at 80°C of CGW-7806 and PPG low-iron float glasses.



ABSORPTION COEFFICIENT
0.5
0.4
0.3
0.2
0.1
0.0
Flattened Tubing
Lab Melt
0.2
0.7
1.2
1.7
2.2
2.7
WAVELENGTH (microns)



CGW-7806
PPG low iron float
WEIGHT LOSS (mg/cm²)
pH
10
1
0.1
0.01
0
2
4
6
8
10
12
14

## ACKNOWLEDGMENTS

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