REVERSIBLE OPACITY PRODUCED IN OPTICAL QUARTZ
BY CONTACT WITH A DENSE PLASMA

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We have found heavy attenuation of the radiation passing through the wall of a quartz capillary evaporating in response to a high-power discharge. The radiation from the end is used with such discharges, so the effect did not affect the results. It is stated [1] that the transmission limit shifts from 160 nm to 220 nm for optical quartz heated to evaporation point by an arc.

Here, we examine the restricted transmission of UV by quartz in contact with a plasma at 20,000 to 60,000 K and 10–500 atm, which produces evaporation rates of 10–30 cm/sec. High heat and light fluxes in quartz can alter the transmission considerably, as can high temperatures and pressures in the adjacent plasma.

First we established the main features of the effect. We used an SP-113M disc spectrochronograph [2] on an ISP-28 quartz spectrograph to scan the spectrum of an arc carrying 50 kA in a tube of internal diameter 15 mm and length 70 mm, the radiation being observed through a quartz window 8 mm in diameter and through a hole 6 mm in diameter in the side. The plasma was at 26,000 K and 100 atm. See [3] for a description of the apparatus. Figure 1 shows that opacity appears at the plasma–quartz boundary as soon as the quartz begins to evaporate rapidly, as detected from the emission of the Si I 288.1 nm line. This occurred in all tests; onset of rapid evaporation was always accompanied by anomalous attenuation of the transmitted radiation. Figure 2 confirms the change in absorption on contact with the plasma.

Fig. 1

Fig. 1. Time scans of channel spectra observed: a) through a hole; b) through a quartz window in contact with the plasma.

Fig. 2

Fig. 2. Emission curves observed: a) from the end of the capillary; b) through the quartz wall.

absorption rises steadily towards short wavelengths; no spectral structure characteristic of molecular absorption in a vapor was observed at 20,000 to 60,000 K and 10–500 atm. The yield of UV falls as the heat flux increases. It has been shown [4] that the plasma T and P vary substantially with the capillary length for a Textolite capillary used at a fixed capillary diameter with a fixed current, whereas the heat flux at the wall and the evaporation rate scarcely alter. This allows one to estimate the effects of plasma parameters on the absorption. We recorded the intensity transmitted by the quartz wall at 245 nm with a current of 9 kA in capillaries 3 mm in diameter and 1, 3, and 5 mm long. These discharge parameters lead one [4] to expect T to vary from 60,000 to 20,000 K and P from 20 to 200 atm. The absorption increased with the plasma density. It is unfortunate that variation in capillary length does not allow one to examine the effect of T and P separately.

Tests were carried out to establish whether the absorption occurs in the heated quartz or in the relatively cool adjacent gas layer. An EV-45 pulsed brightness standard [5] was used to record the absorption spectra. The standard source and the capillary were connected in series.

The gas measurements were made with 9000 Å through a capillary 3 mm in diameter and 3 mm long (Fig. 3A). The reflected ray (observation direction bb') was attenuated only by passage through the boundary gas layer. The transmitted ray (direction aa') showed the full attenuation at the interface. The thickness of the gas layer for the reflected ray was about seven times that for the transmitted ray. It was found that the emission from the plasma adjoining the quartz could be neglected, as could the absorption in the plasma jet.

The ISP-28 spectrograph recorded these spectra, while the SP-113M acted as a fast shutter to isolate the part of the flash where the absorption was maximal. The exposure time was 70 μsec, and the start of the exposure was delayed 60 μsec relative to the start of the discharge. Figure 3B shows the spectra, with the spectrum of the EV-45 source for reference, which was recorded under the same conditions but without the plasma to heat the quartz. The reflection conditions were monitored via spectra recorded before and after passage of the discharge. Throughout the range 200–500 nm, the only prominent absorption in the gas layer is due to Si, I, Si II, and SiO, and the last was seen only when the thickness of the absorbing layer had increased by nearly an order of magnitude. These bands were not observed under any ordinary conditions of observation via the transparent quartz wall. The absorption at the plasma–quartz interface was far greater than that due to the boundary layer of gas alone, e.g., by a factor of more than 5 at 230 nm. Scattering at particles and at the reflecting surface of the quartz was very slight.

The main absorption occurred in the quartz, as was demonstrated via the test of Fig. 4. A rectangular capillary (1.5 × 4 mm) was 40 mm long, one wall being formed by a 60° quartz prism giving total internal