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Preparation and Properties of Low-Loss Glass Optical Waveguides*

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Research on the preparation and characterization of low-loss glass optical waveguides for use in an optical communication system has commanded much international attention during the past few years. The stringent optical requirements placed on such a transmission medium negated the use of conventional glass fiber optics, since their attenuation due to both scatter and impurity absorption were much too high. Thus, unique methods for preparing very high purity glasses in a fiber optic form had to be developed. Our attention was focused on fused silica and high silica glasses, since it was expected their intrinsic scattering and absorption losses would be quite low. However, measurements of transition element absorptivity in fused silica showed that these elements could not be tolerated beyond a few hundred parts per billion in these glasses, due to their strong absorption effects in the projected waveguide use range. In order to minimize the effect of transition elements, glass preparation techniques were developed which involved vapor phase reaction of high purity vapors distilled from liquid starting materials. This modified CVD approach minimized both core/cladding interface scattering losses and impurity absorption losses. It has been successfully used to prepare both single-mode and multimode waveguides of either the step-index or graded-index type from doped fused silica glasses. Total losses as low as 2 dB/km have been measured at 1.06 μm on fibers up to 2 km long.

Fabrication of extremely low loss glass optical waveguides has allowed interpretation of the absorption spectrum to a much greater degree than previously possible. The intrinsic uv absorption edge and the detrimental influence of structural water absorption have been determined. This information has led to the calculation of intrinsic absorption loss. This loss can be below 1 dB/km in the near-ir region of the spectrum. Some progress has been made in reducing the water concentration of these glasses, but the presence of the 950 nm peak is still clearly manifested.

As knowledge of attenuation causes and the ability to control them has increased, other material properties have become of interest. Preliminary measurements of attenuation change with temperature show very small effects in the region around room temperature but rapid increases above about 600°C. Glass fibers are also being examined for the effect of terrestrial radiation, and it has been demonstrated that waveguides can be sufficiently resistant for common installations. Strength studies, an especially complicated topic, are just beginning. Almost all breakage seems to be from surface flaws, and very high strengths are observed in short lengths.

In summary, the knowledge of environmental influences on optical waveguides continues to grow but fails to uncover any barrier to practical use.

* Invited papers.