

Selection of fiber optical waveguide materials

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Since the first achievement of an optical fiber with transmission loss as low as 20 dB/km at the Corning Glass Works in 1970, there has been a rapid expansion in the fiber optical waveguide technology with an associated proliferation in the number of host materials and dopants compounds for fibers. The early work at Corning emphasized fused silica, SiO_2 , as a host material with TiO_2 and GeO_2 as dopants in the core region to produce the well known core-clad waveguide structure. This was followed by work at Bell Telephone Laboratories which introduced B_2O_3 as a cladding dopant in conjunction with a pure silica core. Since then the number of dopants that have been examined range over the entire periodic table of elements. In addition, a large number of host glass compositions have been explored that include various silicate glasses as well as non-silicate glasses, and even polycrystalline halide compounds. The choice of the preferred combination of materials for a given application is sufficiently complicated that in many instances even the experts may disagree. The intent of the present work is to examine the characteristics of various materials and their combinations so that relative advantages and disadvantages can be appreciated and guidelines for selection can be established.

The choice of host materials is governed principally by the spectral range in which transmission is desired. Based on intrinsic transparency, the oxidic glasses are preferred in the visible and near infrared, while chalcogenide glasses and alkali halide compounds have superior infrared transmission. Over the past several years, there has been a growing interest in extending the operating wavelength of fibers to take advantage of decreased Rayleigh scattering. As a general rule, the spectral range of a waveguide can be extended towards longer wavelengths by the selection of heavier elements which tend toward ionic bonding such as TlBr and CsI . This rule is also valid over a more limited range in the selection of dopants for oxidic glasses. However, the more ionic materials, such as Na^+ and K^+ , have been found to be liabilities relative to achieving high mechanical strength. GeO_2 is a better dopant compromise in this case and the preferred host glass composition is still to be identified.

Recent work has established that certain combinations of dopants are preferred for optimizing spectral dispersion in bandwidth and for reducing the response to ionizing radiation in oxidic glass fibers. Underlying all of the above considerations are the economics of selecting materials which can be easily purified and manufactured into waveguides.

纤维光波导材料的选择

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自 1970 年康宁玻璃公司首次获得传输损耗低至 20 分贝/公里的光纤以来,纤维光波导技术已有了迅速发展,其间,用于纤维的基质材料和掺杂物数目也相应地急剧增加。康宁的早期工作着重在熔石英(SiO_2),用它作为掺 TiO_2 和 GeO_2 的光纤芯的基质材料,用来制作众所周知的芯-套波导结构。随后,贝尔电话实验室用 B_2O_3 作包层掺杂剂,以纯石英作芯材。自此以后,经检验过的掺杂剂数目遍及整个周期表的元素。此外,还开拓了大量基质玻璃组分,其中包括各种硅酸盐玻璃,也有非硅酸盐玻璃,甚至有多晶卤化物。对于指定的应用,最优的材料组合的选择是十分复杂的,在许多情况下,甚至专家们亦可能有所争执。现在工作的意图是试验不同材料以及它们相互组合后的特性,以便能正确评价相对的优缺点和建立起选择材料的指南。

基质材料的选择原则上是取决于要求传输的光谱范围。从本征透过率讲,氧化物玻璃在可见和近红外波段是比较好的,而硫系玻璃和碱卤化物具有优越的红外透过特性。在过去几年中,在扩大纤维的运转波长以获得低的瑞利散射的兴趣正在增长。作为一般规律,当选用倾向于形成离子键的重元素后,如 TlBr 和 CsI ,波导的光谱范围能够向较长的波长扩展。在选取氧化物玻璃的掺杂物时,这个规律在更有限的范围内同样也是有效的。然而,已发现离子性强的物质如 Na^+ 和 K^+ 比较倾向于获得高机械强度。在这种情况下, GeO_2 是较好的掺杂剂,而较好的基质玻璃组分仍有待于鉴定。

最近的工作已经提出了在氧化物玻璃光纤中对带宽中光谱色散的最佳化和降低电离辐照响应的掺杂物的某些较好组合。在上述考虑因素之后需要考虑选用材料的经济性,这些材料必须易于提纯和制成波导。