PHYSICAL CHEMISTRY OF FIBRE-FORMING POLYMERS

TEMPERATURE SENSITIVITY OF MULTILAYER OPTICAL FIBRES

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By doping the core of a triplex quartz optical fibre with $P_2O_5$, $GeO_2$, and $B_2O_3$, it is possible to reduce its temperature sensitivity (TS) from $7 \times 10^{-6} K^{-1}$ to $(4-5) \times 10^{-6} K^{-1}$. The same decrease in TS can be obtained by doping the third layer with $TiO_2$. The doping level in both cases should be 30-40 mole %. The TS of an optical fibre greater than 80 μm in diameter is almost not a function of random changes in the diameter. For a liquid-crystalline polymer cladding above a fixed value, the TS of the fibre is weakly dependent on the change in the thickness.

Increasing the quality and efficiency of use of chemical fibres and thread is to some degree dependent on the methods of process control in their manufacture and use. Multilayer optical fibres which are compatible in technology and design with the fibres investigated are used as control sensors in many cases.

As a function of the problem to be solved, the parameters of a multilayer optical fibre should be specially optimized. The temperature sensitivity of the fibre, determined by coefficient $K_t$, is of primordial interest. In particular, the structure (material and geometry of the layers) of the fibre should be selected so that small variations in the structure arising during its manufacture would not cause large changes in $K_t$.

The optical fibre in design is a $q$-layer ($q = 2, 3, 4, \ldots$; the first layer corresponds to the core, the second to the cladding, the third to the technical cladding, etc.) structure, whose layers have different thermal, elastic, and optical properties [1, 2]. The temperature sensitivity of such a fibre is a function of a multitude of parameters, which causes great difficulties in determining the structure of special fibres with assigned technical characteristics.

The effect of doping the core, third layer, and the liquid-crystalline polymer cladding on the temperature sensitivity of triplex quartz optical fibres with different geometry and structure is examined here.

The change in $K_t$ can be caused by both a change in the parameters of the fibre material — Young’s modulus ($E_m$), Poisson’s ratio ($\nu_m$), coefficient of thermal expansion (CTE — $\alpha_m$), and a change in the geometry of the layers — area of the cross section ($S_m$), radius ($r_m$) of the layers of the fibre ($m = 1, 2, 3, \ldots, q$ corresponds to the layer number). Relatively slight doping of molten quartz with $P_2O_5$, $GeO_2$, $B_2O_3$, and $TiO_2$ significantly changes primarily its CTE, and with a concentration of oxide of less than 30%, the CTE of molten quartz increases linearly with an increase in the concentration of $P_2O_5$, $GeO_2$, and $B_2O_3$ and decreases linearly with an increase in the concentration of $TiO_2$. The CTE ($\alpha$) of molten quartz as a function of the concentration of oxide (Y, mole %) can be written as follows:

$$\alpha = (0.5 + KY) \times 10^{-6} K^{-1}, \quad (1)$$

where $K = 0.13$ (mole %)$^{-1}$ for $P_2O_5$, 0.07 (mole %)$^{-1}$ for $GeO_2$ and $B_2O_3$, and $0.1$ (mole %)$^{-1}$ for $TiO_2$.

For a low concentration of oxide, the temperature sensitivity of a quartz optical fibre as a function of doping is thus reduced to the dependence of $K_t$ on CTE.

We will first investigate the temperature sensitivity (TS) of a triplex optical fibre. The curve of TS of a triplex fibre as a function of the thickness of the third layer ($h_2 = r_3 - r_2$) for different values of CTE of the first and third layers is...
Fig. 1. TS of a triplex optical fibre vs. thickness of the third layer for different coefficients of thermal expansion (CTE) of the first and third layers.

Fig. 2. TS of a triplex optical fibre vs. CTE of the first layer ($X_1$).

Fig. 3. TS of triplex optical fibre 120 µm in diameter vs. CTE ($X_5$) and thickness ($h_5$) of the liquid-crystalline polymer cladding.