U.P.B. Sci. Bull., Series B, Vol. 71, Iss. 3, 2009 ISSN 1454-2331

CARACTERIZATION OF THE STRUCTURE AND CHEMISTRY OF OPTICAL FIBER

Daniela Beatrice COŞMELEAŢĂ[1], Simona ZAMFIR[2]

Lucrarea prezintă caracterizările efectuate ce au permis evaluarea structurii şi proprietăţilor fibrelor optice pe bază de SiO_2 pentru doua categorii de fibre optice: fibre optice monomod şi multimod. S-au determinat spectrele de emisie a radiaţiilor X şi analiza cantitativă a compoziţiei chimice pentru miez, manta şi cele două straturi protectoare pentru fibra optică multimod cu 8 fire şi difractograma fibrei optice multimod cu 8 fire realizata cu un difractometru care a utilizat radiaţii cu lungime de undă λKα = 1,79 Å, emisă de un catod de cobalt.

The experimental characterizations carried out in this paper allowed the evaluation of the structure and properties of SiO_2-based optical fibers for two categories of optical fibers: mono-mode and multi-mode optical fibers. The emission spectra of X radiations and the quantitative analysis for the core, cover and the two protective layers for the multi-mode optical fiber with 8 wires have been performed. The diffractogram of the multi-mode optical fiber with 8 wires recorded with a diffractometer using radiations with wave length λKα = 1,79 Å, emitted by a cobalt cathode, has put in evidence an amorphous structure.

Keywords: optical fibers, ESEM; quantitative analysis, diffractogram

1. Introduction

In the field of optical fibers the research efforts are oriented towards two main directions: finding some materials with superior characteristics; and developing and applying some modern technologies able to result in products with high quality features, at very accessible prices.

Regardless of the chosen composition the dielectric material used to obtain optical fibers must meet the following general requirements: to have a very good transparency for the wave length of the light signal used; to have an as good as possible chemical stability in time; to be easily processable in all the steps of the operating process *[1]*.

On the basis of the experience of optical fiber producers, the materials with the longest use may be grouped in three categories: pure silicon dioxide and

[1] Ph.D. student, Department Materials Science and Physical, University POLITEHNICA of Bucharest, Romania, danic@stnet.ro

[2] Professor, Department Materials Science and Physical, University POLITEHNICA of Bucharest, Romania

its mixtures with other oxides in small quantities, also called dopants; multi-composite glasses; plastic materials *[2]*.

Robert Maurer, Donald Keck and Peter Schultz *[3]*, researchers at 'Corning Glass' have invented the OPTIC FIBER, capable to transmit 65,000 times more information than the copper wire and the transmitted information may be decoded even at 1000 km distance.

In 1977, the first telecommunication system by optic fiber was installed in Chicago city, each optic fiber being able to transmit the equivalent of 672 voice channels.

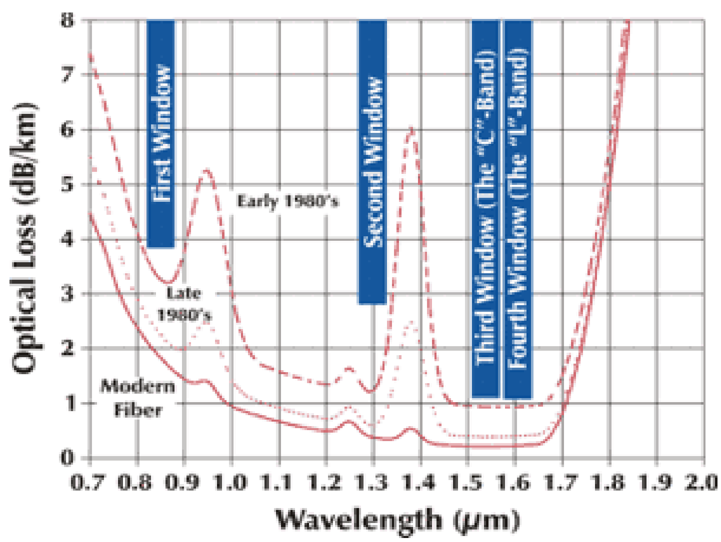


Fig. 1. Four Wavelength Regions of Optical Fiber: the beginning of 1980's; - the end of 1980's and the modern epoch of optic fiber *[4]*.

At the beginning of the 1980's, they already installed millions of kilometers of optic fiber and optic fiber communication systems (OFCS) clearly exceeded the performances of the electric communication systems on the buses with speeds higher than 8 Mb/s.

In a time interval of about 20 years (1970-1990), they made and introduced in exploitation several OFCS generations (three generations according to some authors, and four or five according to others), at present they being able to make systems with speeds of more than 10 Gb/s and lengths for the regeneration of the optic signal of more than 100 km (Fig. 1) *[4]*. The increase of the transmission capacity between 1980 up to now is illustrated in Fig. 2 *[4]*.

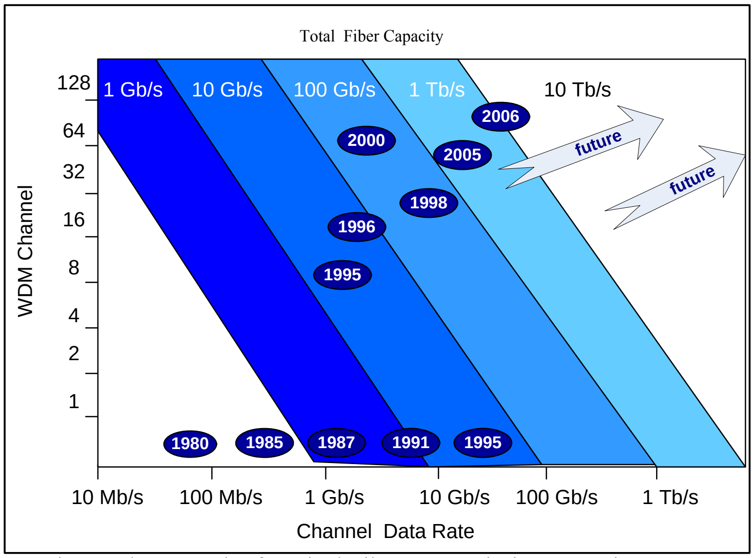


Fig. 2. The Growth of Optical Fiber Transmission Capacity *[4]*

The optic fiber communication systems (OFCS) are widely spread: in the local networks and in the large buses; in the public, private, terrestrial, underwater and cosmic networks. The numeric systems with IMDD (intensity modulation - direct detection); -the systems with numeric modulation of a subcarrier (modulation in amplitude, time, position, frequency) having the advantage of numeric detection are very widely spread *[5]*.

The primary advantages obtained when using optical fiber are: very large band width, reduced size and weight, electrical isolation, unit to interferences and intercommunication, small loss during transition, system stability and the low need for maintenance and the low consumption of electricity. All these make that transmission by the optical fiber to be very attractive within the national and international communication networks.

The present papers aims at the evaluation of the structure and properties of SiO2-based optical fibers both for: mono-mode and multi-mode optical fibers.

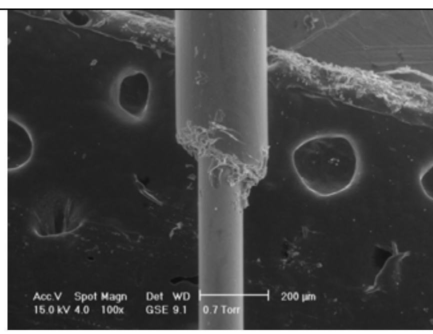
2. Results and Discussion

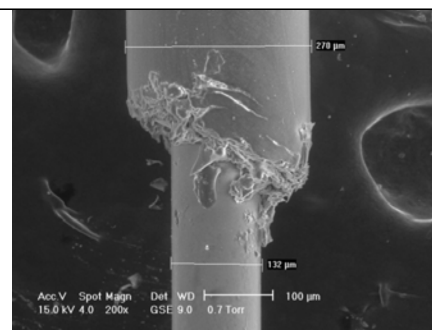
Two categories of optical fibers have been analyzed mono-mode optical fibers and glass multi-mode fibers with 8 wires. We have noticed that between the optical and mechanical qualities of the fiber and its geometrical characteristics there is a very tight link. In fact, among the geometrical characteristics a special role is played by the core diameter and the diameter of optical cover as well as the state of fiber surface. The variation of the values of the two diameters has unwanted influences over the propagation of light within the fiber whereas the flaws of the external surface lead to the decrease of mechanical resistance. In order to go deeper in this correlation we have used optical and electron microscopy to characterize the structure and chemical composition of the investigated optical fibers. For this purpose we have used an optical microscope type and an electron microscope type XL-30-ESEM TMP. To characterize the fine structure a diffractometre BRUKER-AS type D8 ADVACE *[6]* has been used.

The optical micrographs presented in Figs. 3 and 4 clearly put in evidence the optical pure glass layers: a central cylindrical nucleus, called core (which in the case of mono-mode optical fibers is about 132 μm) and an optical cover enveloping the core that has the property of totally reflecting the light (whose thickness – for the same type of mono-mode optical fibers – is about 270 μm).

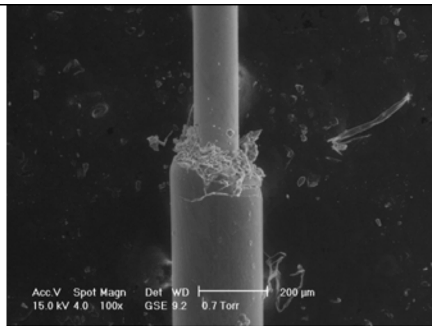
The core and coat are covered by a primary inner protective coat from plastic material (acrylate, polyamides) for the protection of the fiber against mechanical deterioration (abrasion) or chemical processes and a secondary layer made of plastic material giving the necessary consistency for the manipulation of the fiber.

The two layers are made of materials with different refraction index, the refraction index of the optical cover being less than that of the core. The micrographs recorded were recorded at magnifying powers of 100; 200 and 320 respectively.

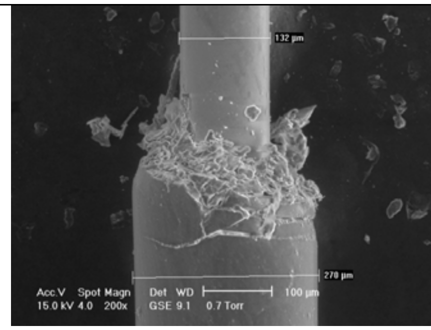




a) X100	**c) X200**



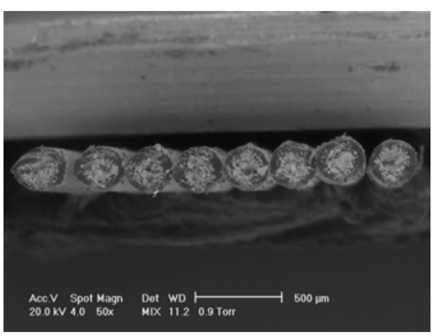
b) X100



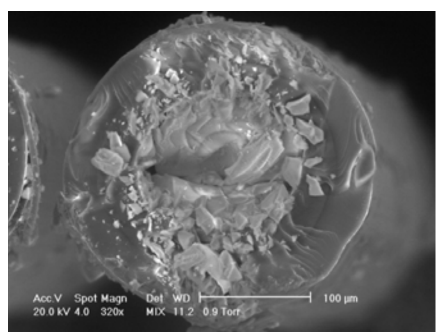
d) X200

Fig. 3. Optical micrographs for mono-mode glass fibers *[7]*

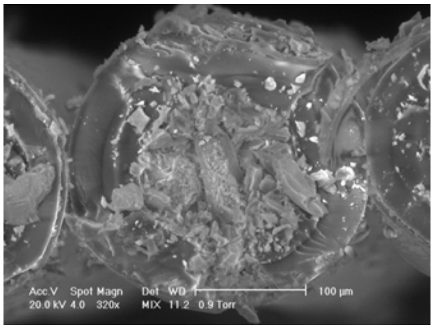
One may notice particles of polyhedral shape, with plate plaque-like aspect and a wide size distribution. From the analysis of these micrographs, we noticed that the protective cover (made from glass) is at its turn made of two coaxial layers: one in the interior, protective, and another with a higher elastic modulus, both united between them by the polymerization procedures of the acrylic resin *[7]*.



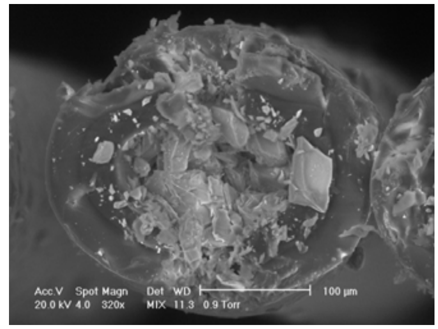
a)



b)



c)



d)

Fig. 4. Optical micrographs for multi-mode glass fibers with 8 wires *[7]*

As we already mentioned, between the optical and mechanical qualities of fiber and its geometrical features there is a very tight connection. In fact, among the geometrical characteristics a special importance is held by the core diameter and the one of optical cover as well as the state of fiber surface (Fig. 3-4) *[7]*.
The variation of the values of the two diameters has unwanted influences on the propagation of light within the fiber, whereas the flaws of the external surface lead to the decrease of mechanical resistance.

The investigation of the two layers, from the structural and compositional viewpoint, was performed by SEM electron microscopy making at the same time the qualitative and quantitative compositional analysis (by means of the EDAX device equipping the electron microscope) as well as the distribution of the elements over the entire surface of the analyzed sample *[6]*.

Thus we have determined the emission spectra of X radiations (Fig. 5-7) and the quantitative analysis (tables 1-3) for the core, cover and the two protective layers for the multi-mode optical fiber with 8 wires *[7]*.

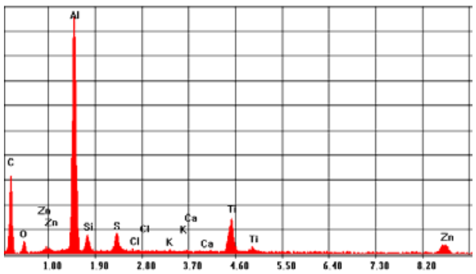


Fig. 5. Chemical composition of the cover of multi-mode optical fiber with 8 wires *[7]*

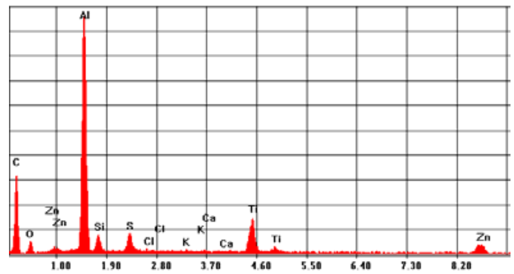


Fig. 6. Chemical composition of 1st protective layer of the multi-mode optical fiber with 8 wires *[7]*

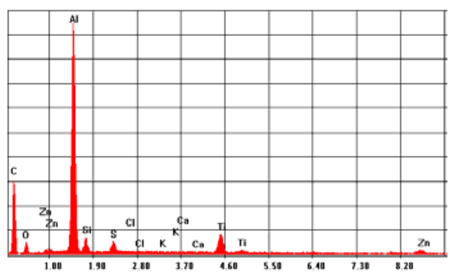


Fig. 7. Chemical composition of 2nd protective layer of the multi-mode optical fiber with 8 wires *[7]*

Table 1-

Quantitative analysis of elements in the cover of multi-mode optical fiber with 8 wires*[7]*

Element	Wt %	At %	K-Ratio	Z	A	F
C	61.26	79.66	0.1522	1.0381	0.2392	1.0001
O	5.25	5.13	0.0082	1.0207	0.1525	1.0004
Al	16.97	9.82	0.1146	0.9508	0.7095	1.0012
Si	1.48	0.82	0.0094	0.9786	0.6512	1.0011
S	1.68	0.82	0.0134	0.9611	0.8320	1.0017
Cl	0.18	0.08	0.0015	0.9194	0.8813	1.0026
K	0.13	0.05	0.0011	0.9268	0.9580	1.0074
Ca	0.17	0.07	0.0016	0.9489	0.9788	1.0130
Ti	5.44	1.77	0.0474	0.8665	1.0018	1.0046
Zn	7.45	1.78	0.0625	0.8314	1.0092	1.0000
Total	100.000	100.000				

Table 2

Quantitative analysis of elements in the 1st protective layer of multi-mode optical fiber with 8 wires [7]

Element	Wt %	At %	K-Ratio	Z	A	F
C	64.91	80.32	0.1756	1.0295	0.2627	1.0001
O	7.01	6.51	0.0109	1.0123	0.1542	1.0003
Al	17.54	9.66	0.1277	0.9431	0.7714	1.0011
Si	1.45	0.77	0.0096	0.9707	0.6823	1.0009
S	1.11	0.52	0.0090	0.9518	0.8541	1.0014
Cl	0.20	0.09	0.0017	0.9107	0.9027	1.0022
K	0.14	0.05	0.0013	0.9185	0.9707	1.0060
Ca	0.21	0.08	0.0020	0.9406	0.9885	1.0099
Ti	3.91	1.21	0.0339	0.8588	1.0074	1.0025
Zn	3.52	0.80	0.0293	0.8232	1.0108	1.0000
Total	100.000	100.000				

Table 3

Quantitative analysis of elements in the 2nd protective layer of multi-mode optical fiber with 8 wires *[7]*

Element	Wt %	At %	K-Ratio	Z	A	F
C	74.92	85.01	0.2575	1.0160	0.3383	1.0001
O	7.86	6.70	0.0123	0.9991	0.1566	1.0002
Mg	0.27	0.15	0.0018	0.9590	0.6968	1.0057
Al	13.78	6.96	0.1063	0.9309	0.8283	1.0008
Si	1.37	0.66	0.0099	0.9582	0.7527	1.0003
S	0.32	0.13	0.0027	0.9374	0.9016	1.0004
Cl	0.24	0.09	0.0020	0.8972	0.9457	1.0002
Ti	0.38	0.11	0.0033	0.8468	1.0193	1.0012
Cu	0.87	0.19	0.0072	0.8112	1.0158	1.0000
Total	100.000	100.000				

The X-ray diffraction pattern of the multi-mode optical fiber with 8 wires recorded by means of a diffractometer using the wavelength $\lambda K\alpha$ = 1,79 Å, emitted by a cobalt cathode is given in Fig. 8.

We may notice a high intensity peak at 2 θ = 21,7° and several weaker intensity peaks at 2 θ = 37,6; 42,9; 47,6°.

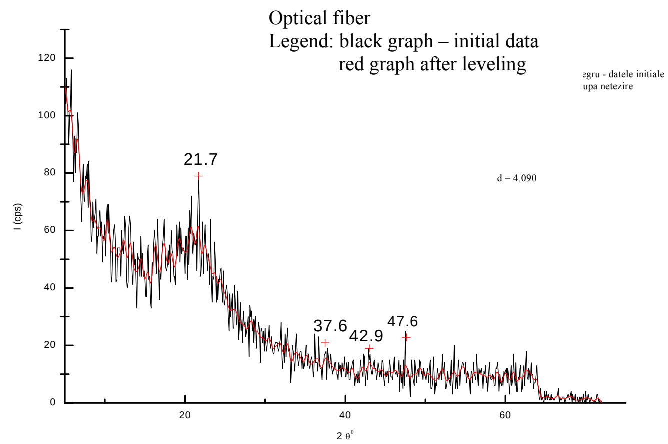


Fig. 8. Diffractogram of multi-mode optical fiber with 8 wires *[7]*

These diffractograms obtained at large diffraction angles, $2\theta \geq 10^{o}$, presenting a large width peak (and not large intensity peaks) for certain diffraction angles - specific to the materials with crystalline structure – show that the material has an amorphous structure *[7]*.

3 Conclusions

The experimental characterization leads to the following conclusions:

1. The optical micrographs indicate that, in the absence of the cover, the optical fiber is made from a mixture of glass fibers with variable diameters presenting a very high fragility. The optical fibers analyzed are made of two layers of pure glass: a central cylindrical nucleus, called core (which in the case of mono-mode optic fibers is about 132 μm) and an optical cover covering the core and that the property to totally reflect light (whose thickness – for the same type of mono-mode optical fibers – is about 270 μm).
2. Among the geometrical characteristics a special importance is held by the core diameter and the one of optical cover as well as the state of fiber surface. The variation of the values of the two diameters has unwanted influences over the propagation of light within the fiber whereas the flaws of the external surface lead to the decrease of mechanical resistance.

3. From the quantitative analysis of the core of the investigated optical fiber it results that it is a multi-composite glass fiber with a concentration of the silicon oxides of 80%-90% and doped with Al_2O_3 and with GeO_2. This doping helps increasing the refraction index and dispersion.
4. The diffractograms recorded at high diffraction angles, $2\theta \geq 10^{o}$, have a large width peak meaning that the material has an amorphous structure.

R E F E R E N C E S

[1] International Telecommunication Union (ITU), Recommendation G.692 - Transmission media characteristics – Characteristics of optical components and sub-systems, 1998
[2] *Adrian Mihăescu* – Optical Communications, Editura de Vest 2004
[3] *Robert Maurer, Donald Keck, Peter Schultz* -"Optical Waveguide Fibers" (patent #3,711,262-invented fiber optic wire)
[4] *David R. Goff*, Fiber optic video transmission: the complete guide, Focal Press, 2003
[5] *Jeff Hecht*, City of light: the story of fiber optics , Oxford University Press 2004
[6] *D. Bojin, Fl. Miculescu, D. Bunea, M. Miculescu*, Electronic microscopy of sweeping and applications, Editura Agir 2005
[7] *Daniela Coşmeleaţă*, doctoral thesis “Studies and researches concerning the factors that influence the structural and the exploitation characteristics of the fiber optics used in the transmitted date networks”, University POLITEHNICA of Bucharest, 2009.