High temperature resistant coatings for optical fibers

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The preparation of metal coated fibers via metallization of organometallic precursors opens a new approach to manufacture high temperature resistant optical fibers inside the fiber drawing process. This metal coating technique is compatible to a wide range of fiber drawing parameters (e.g. fiber drawing speed, fiber diameter). The technique applies conventional fiber coating systems, like pressure coating deposition and thermal curing devices. We discus preparation aspects and performance of gold coated fibers.

1 Background

Metal coated fibers open new possibilities for high temperature applications, e.g. Fiber Bragg Grating Sensors. However, typical methods for metal coating of optical fibers show drawbacks. The metal freezing method has the disadvantage of high thermal loading of the fiber using metals with high melting temperature (e.g. gold, platinum). This strongly degenerates the previously written Fiber Bragg Gratings. The high surface tension, the critical wettability and the very low viscosity of metal melts complicate the deposition of axial and radial homogeneous metal coatings [1]. Other methods like sputter deposition require vacuum precipitator devices. This complicates the installation of the metal coating process inside the fiber drawing equipment [2]. The investigated metal coating method is based on metal organic precursors operating with conventional polymer coating applicator and thermal curing under atmospheric conditions.

2 Preparation

The metal coated fibers were manufactured by deposition of metal organic fluid on the fresh drawn fiber and subsequent thermal decomposition of the fluid to metal. The investigated coating material was gold. The starting material was a mixture of gold sulforesinate, natural and synthetic resins, and solvents (W.C. Heraeus GmbH). The optical fibers were drawn from a preform of high purity silica (Heraeus Suprasil F300) to a diameter of 125 µm. Subsequently, before first mechanical contact with the capstan wheel, the fibers were coated with the gold resinate fluid. We used the pressurized coating technique with coating dies of diameters 150 µm and 180 µm. The metallization results by thermal oxidation of the organic components of the gold solvent.

3 Characterisation

Figure 1 shows the thermal decomposition of the gold resinate, measured by thermal gravimetric analysis (TG) up to a temperature of 700°C in air. The metal content of the starting material was 22 wt.%. The analysis shows, that the conversion to the pure metal is incompletely in solely a single run.

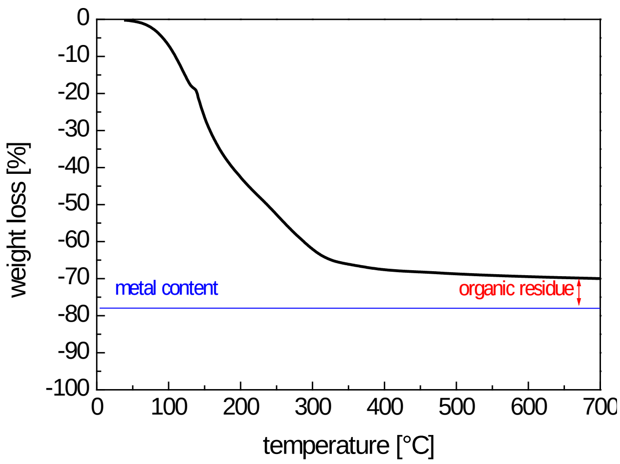

***Fig. 1** Thermogravimetry (TG) of the gold resinate in air with heating rate 10K/min up to 700°C*

The remaining organic residue is about 8 wt.%. It is completely removed after passing a second heating run at maximum temperature of 500°C.

The final thickness of the gold coating layer is a few hundreds nanometers corresponding to the strong volume shrinkage during metallization of the resinate. Figure 2 shows the cross section metalized fiber surface. The thickness of the metal layer is about 300 nm.

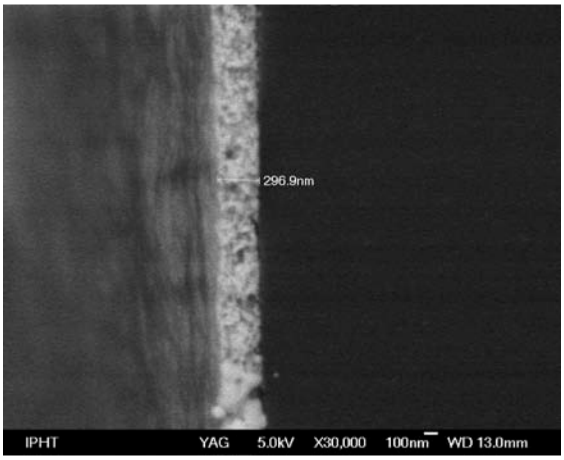

Fig. 2 *SEM micrograph of a gold coated fiber manufactured by pressurized resinate coating method*

The small thickness of the gold layer limits their tightness. Figure 3 shows the porous topology of the metalized fiber surface. Additionally we find scratch marks and holes.

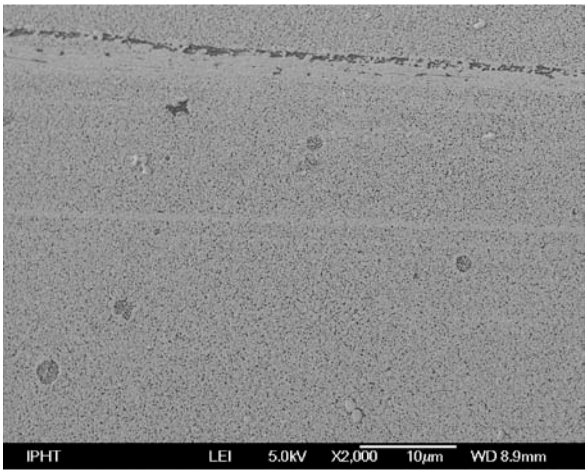

Fig.3 *SEM micrograph of the gold coated fiber surface*

The thermal behaviour of the gold film was investigated by hot stage microscopy with a heating rate of 10 K/min. The gold film shows a thermal resistivity up to 950°C in air atmosphere without visible degradation. At higher temperatures (>975°C) we found sintering and surface migration. The further increase of temperature causes the formation of small drops by combination of melting and surface tension effects.

It would be expected, that a larger thickness would improve the reliability of the metal coated fiber. One approach is the increase of resinate deposited thickness by larger coating dies. Though, the increase of the resinate thickness up to 27 µm causes an heterogeneous gold film of about 1.2 µm. However, this gold coating shows a low adhesive strength and high delamination tendency. Possible causes are to be seen in limitations of decomposition kinetics and limits of the reaction product diffusion rate during the metallization of the resinate.

On the other hand, the thin gold film (300 nm) shows a low electric resistance over fiber length of about 9 Ω/cm. This conductibility allows the deposition of a second metal film by galvanic precipitation, e.g. silver. Advantageously this process can be operated separately from fiber drawing procedure and expects large, corrosion resistant metal films. The thickness can accomplished up to a few tens micrometers.

4 Summary

The coating of optical fibers by gold film deposition via decomposition of metal resinates opens a new approach for metallization of fibers during fiber drawing process. It uses the pressurized coating technique known from fiber coating with polymers. The thickness of a homogeneous, abrasion-resistant single pass gold layer is limited to few hundred nanometers. Though, this layer shows a certain porosity. The electric resistance is low. This allow the deposition of hermetically sealed secondary metal films by galvanic methods, independent from fiber drawing.

The resinate based metallization technique allows the variation of the fiber drawing parameters in a wide range. In contrast to other metallization techniques of silica fibers (e.g. metal freeze coating, metal sputtering) the resinate technique facilitates the preparation of online written Bragg Grating fibers with approved technological parameters.

References and Acknowledgment

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