A silica fibre with a thin lead wire in the core

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Abstract

We have manufactured a Duran fibre with a thin lead wire in the core. A wire diameter of $2.25 \ \mu m$ has been reached. Lengths in the order of one meter have been produced. The integrity of the core was confirmed electrically.

Introduction

Metal wires can be drawn to very small diameter when they are incorporated in the centre of a glass fibre preform. As the preform is drawn to a thin fibre, also the metal wire is reduced in diameter. There is some hope to use this technique to produce nanowires of arbitrary length. Besides the fascinating properties of nanowires [1] there is also the possibility to modify the properties of an electromagnetic wave guided in a core with such a thin metal wire [2, 3]. In [2] the fabrication of a silica fibre with integrated gold wire was tested. It could be shown that after a first drawing step gold wires of 20 μ m diameter with lengths of several cm are found. After a second drawing step, gold wires as thin as 2 – 4 μ m with mm lengths can be produced. It was shown that limitations that prevent the generation of nm-sized gold wires are due to a local overpressure of evaporated silver contained in the gold wire and to the high surface tension of gold of 0.731 Nm⁻¹ [4, F-24] at the melting point.

These problems, however, can be solved with a more suitable choice of the material. Based on the results of [2] it was assumed that evaporation of material is more destructive than the surface tension. Therefore an experiment was made with platinum. The high surface tension of platinum of 1.865 Nm⁻¹ [4, F-32] prevented the fabrication of a thin wire. All the platinum was found in shape of small droplets. Clearly another solution has to be found. In order to avoid evaporation it is favourable to replace silica with Duran glass and thus to reduce the drawing temperature from about 1900°C to about 1200°C. A good candidate is lead with a surface tension of only 0.451 Nm⁻¹ [4, F-32].

In the present paper we report on an experiment with integration of a lead wire in a Duran glass capillary.

Experiments and results

A 10 cm length of a 0.5 mm diameter lead wire of highest purity (Goodfellow 99.999%) was introduced into a 5mm by 0.6mm diameter Duran glass capillary. The capillary is sealed off at its lower end. With a blow dryer capable to reach about

 600° C the lead is molten in order to tightly fill the lowest 7 cm of the glass capillary. The filled capillary is mounted in the drawing tower and drawn to a fibre of about 20 μ m diameter.

As in the case of gold wires [2] the purity of the material is a crucial property to avoid evaporation and overpressure of the preform during the drawing process. An experiment with lead of lower quality (nominal 99.999% from a different supplier) led to complete destruction of the preform.

Fig. 1 shows an electron micrograph of the produced fibre.



Fig. 1: Electron micrograph of a Duran glass fibre with lead core. The fibre diameter is 21 μm and the diameter of the lead core is 2.8 μm.

A different piece of the fibre with a diameter of 18 μ m was broken in such a way that the lead wire sticks out for about 15 μ m. A scanning electron micrograph is shown in Fig. 2.



Fig. 2: Scanning electron micrograph of a broken 18 μm fibre with the lead wire sticking out for about 15 μm.

In Fig. 2 the lead wire has a diameter of 2.25 μ m.

In contrast to [2] where only mm lengths of micron wires could be produced, the present experiment allowed production of meter lengths. With a measurement of conductivity the integrity of the wire has been tested. In a first experiment a 30 μ m fibre with 3.6 μ m wire diameter and 6 cm length was glued on a sheet of Perspex with conductive silver. A measurement with an ohm-meter showed a resistance of about 10 k Ω . This resistance is mainly due to the conductive silver contacts. Using a specific conductance of 20.6 $\mu\Omega$ cm [4, F-159] would lead to a resistance of the wire of only 1.21 k Ω . Nevertheless, this test showed that the 6 cm length was free of interruptions. This measurement confirms the visual inspection in a microscope.

Experiments were performed to further reduce the wire diameter with a second drawing step. To this end a thick piece of the fibre with a diameter of 0.2 mm, situated just behind the drop was introduced into a Duran capillary of 5 mm by 0.6 mm diameter and, again, drawn to a fibre. Even after several attempts with the second drawing no thin wires were found, all visible lead was molten to small droplets.

Conclusion

In conclusion we have manufactured a Duran fibre with a thin lead wire in the core. A 99.999% purity lead wire was filled into a 5mm by 0.6mm diameter Duran glass capillary. The lead was molten with a blow dryer to tightly fill the capillary. The filled capillary was mounted in the furnace of the drawing tower and drawn to fibre of about 20 μ m diameter. A wire diameter of 2.25 μ m has been reached. Lengths in the order of one meter have been produced. The integrity of the core was confirmed electrically and by visual inspection in a microscope.

Acknowledgments

We thank M. Neff, M. Mühlheim and R. Scheidegger for their help in the drawing tower. D. Weber, A. Luder, and N. Jaussi we are grateful for their help with conductivity measurements.

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