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Filiform Nanostructure Technologies Based on Microwire Stretching

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A technological route allowing one to integrate huge amounts of electrically isolated metal, semiconductor, or semimetal nanowires in glass fibers with the diameter of up to a few hundreds of micrometers is presented, and the perspectives of implementation of these filiform nanostructures in concrete devices are described, particularly in photonic crystal lenses. The technology is based on a multiple stretching process. We found that a relationship between the main technological parameters including surface tension of the core material, tensile force and glass viscosity should be satisfied in order to provide continuity of the core. The possibility of integrating hundreds of thousands and even millions of glass-encapsulated nanowires is demonstrated.

Keywords: Nanowires, Filiform Nanostructures, Microwire Preform, Stretching.

1. INTRODUCTION

Nanowires of various materials such as metals and their alloys (including those with superconducting and magnetic properties), semiconductors and semimetals are emerging advanced multifunctional materials for microelectronic, photonic and biomedical applications. Integration of a large amount of nanowires in a super-array is imperative for many applications. Nanowires based on various materials have been successfully produced by vapor–liquid–solid synthesis on seeded substrates,[1,2] thermal evaporation,[3] electron beam evaporation[4] etc. Different templated nanofabrication techniques are usually used to fabricate large assemblies of nanowires with templates based on alumina or silica, ion tracked inorganic materials, and semiconductor nanosieves.[5–7] These techniques, however, allow one to produce arrays of nanowires with a maximum length of a few hundreds of micrometers. In order to increase the length of nanowires and, therefore, to extend the area of possible applications, it has been proposed to produce filiform nanostructures (FNS) in a densely packed array of isolated nanowires in glass envelopes.[8,9] This method is based on heating and stretching a preform consisting of stacked microwires in glass envelope to reduce the diameter of microwires to nanometer dimensions. A modification of this method has been proposed which consists in a multiple thinning of a bundle of glass tubes filled with thermoelectric material powder heated up to the melting temperature during the stretching process.[10]

Recently, we demonstrated an efficient technological route for the integration of record amounts of metal or semimetal nanowires in a human-hair-like glass fiber, the length of the fiber reaching 100 cm.[11–13] The proposed route comprises (a) the formation of a metal or semimetal microwire in glass insulation by capillary drawing from the bottom of a glass tube softened by a conducting melt drop levitating in the high-frequency electromagnetic induction field; (b) mechanical assembly of a bundle from equal length cut microwires which are distributed in a 2D hexagonal densely packed lattice encircled by a joint glass envelope; (c) stretching of the obtained preform under suitable heating conditions to reduce the diameters of the stacked microwires; and (d) repeating the cut-assembly-stretching processes for the purpose of further decreasing in transverse dimensions of constituents down to tens of

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