The Ultimate Strength of Silica Nanowires

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Silica nanowires (SN) manufactured from optical fibers using a top-down approach have in the recent years attracted much attention because of their use for photonic applications and sensors. Until 2003, surface roughness and inhomogeneity appear to have limited the use of SNs for optical applications [1].

SN and sub-wavelength wires offer a number of unique optical and mechanical properties, including: 1) Large evanescent fields; 2) High nonlinearity; 3) Extreme flexibility and configurability; and 4) Low-loss interconnection to other optical fibers and fiberised components. In fact SN are fabricated by adiabatically stretching optical fibers and thus preserve the original dimensions of the optical fiber at their input and output allowing the manipulation of a single nanowire without the expensive instrumentation typical of the nanoscience and nanotechnology worlds.

In this paper the mechanical strength of SN manufactured from optical fibers using the modified flame-brushing technique [2] is presented. Tapers with a sub-micrometric diameter and transitions of well defined length and shape were produced by scanning a microheater (NTT-AT, Japan) over 6 millimeters along the optical fiber while the fiber was pulled by two high-precision translation stages. The radius of the SN varied between 60 and 300nm. The ultimate strength σ_f, defined as the maximum stress a material can withstand, was measured by adding milligram masses at the lower extremity of the nanowire while held vertically until fracture occurs [3]. The total mass is then measured using a scale with 0.1 mg accuracy and the stress derived using a calculation area $A=\pi r^2$ (where r represents the SN radius at the end of fabrication, with no added weight). Figure 1 presents the ultimate strength in as-manufactured SN and it shows that σ_f is higher than that measured in bare optical fibres with r=62.5 μm (σ_f =5 GPa) [4]. In particular, for SN with r<200nm σ_f is in excess of 10 GPa. Although this value is below the value measured for carbon nanotubes (σ_f =21-63Gpa [5]), it is still considerably larger than the values recorded for high strength steel ASTM A514 (σ_f =0.76Gpa) and Kevlar (σ_f =3.88Gpa)

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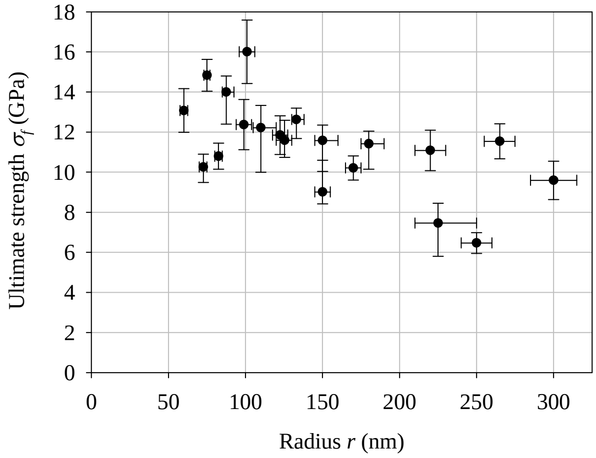

Fig. 1. Dependence of the ultimate strength of silica nanowires on the nanowire diameter.