An updated review of nanotechnologies for the space elevator tether

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The space elevator tether requires an extraordinary specific ultimate strength $\sigma_\rho$ (ratio between ultimate strength $\sigma$ and density $\rho$) and carbon nanotubes (CNTs) have been identified as the ideal candidate because of their astonishing strength$^{1,2}$ ($\sigma_\rho > 60 \text{MYu}r$) for CNT manufactured by CVD with radii in the region of $r \approx 50 \text{nm}$, fig. 1). Yet, the highest values of $\sigma_\rho$ were measured on samples only few microns long$^{1,2}$ and long tethers are as strong as the weakest link. Indeed, the fabrication of flawless wires has been proved very challenging. Since 2007 reports of CNTs longer than 15mm have become common (a single CNT as long as 300 mm was allegedly made at the MIT Institute for Soldier Nanotechnologies in 2009) and CNT bundles longer than 18mm have also been achieved; unfortunately their $\sigma_\rho$ has not been reported, yet.

An alternative path to manufacture km-long tethers with $\sigma_\rho > 20 \text{MYu}r$ could rely on the possibility to join different CNTs$^3$ with joints as strong as the CNT themselves$^4$, if parallel processing can be employed.

Finally, combinations with other high-$\sigma_\rho$ nanowires can be envisaged: in the last few years, four types of nanowires with $\sigma_\rho > 5 \text{MYu}r$ have been reported in the literature; fig. 1 summarizes the data on silicon carbide$^5$ (SiC), silicon nitride$^6$ (Si$_3$N$_4$), and silica$^7$ (SiO$_2$). SiC and Si$_3$N$_4$ at their best can provide $\sigma_\rho > 16 \text{MYu}r$, while the greatest value reported for silica glass is smaller, $\sigma_\rho \approx 12 \text{MYu}r$. The great benefit of these nanowires relies in their possibility to be manufactured in extremely long lengths with minor changes to the current fabrication technology: silica glass allows for the prompt manufacture of km-long wires. Si$_3$N$_4$ can also be manufactured in relatively long lengths with the current technology, but the length of defect free Si$_3$N$_4$ single crystals has never been tested.

Reference
3) Q. Cui et al., Small 5, 1246 (2009).
7) G. Brambilla et al., Nano Lett. 9, 831 (2009).