카본나노튜브 섬유 직접방사 기술의 과거, 현재 그리고 미래

융복합섬유팀

F. Smail et al., Carbon. 152, 2019, 218-232

- It is now 14 years since the publication of the first paper describing the continuous production of carbon nanotube fibres by the direct spinning process.

- To some extent structure property type research has outstripped studies to understand and eventually scale up the production process itself.

- Progress is such that the axial mechanical strength and stiffness of carbon nanotube fibers are already competing with other high performance fibers such as aramid, polyethylene and carbon, while both the electrical and thermal conductivities are one to two orders of magnitude better than PAN based carbon fiber.

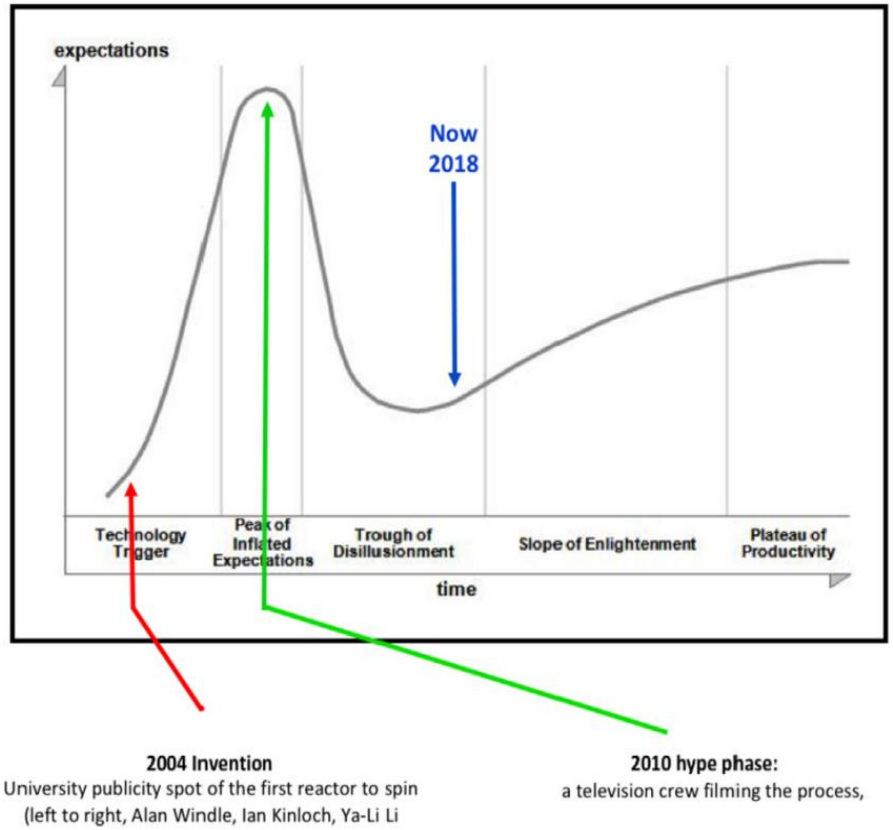
- However, to undercut other high performance fibers on price while at the same time providing a wider ranging property spectrum, requires scale-up, although comparatively few publications in the literature have focused on this.

- Here the various key parameters which will come to bear during large-scale plant design are addressed, especially those associated with hydrogen supply and management.

F. Smail et al., Carbon. 152, 2019, 218-232

A Gartner ‘hype’ cycle

❖ **A Gartner ‘hype’ cycle for the development of the CNT fiber technology**



- The pathway from inventive step to industrial scale production is tortuous and is summarised by the Gartner diagram
- Much of this paper however, is looking up the slope which is now being climbed towards commercial large-scale production, with the initials stages of scale up in the hands of TorTech Nano-fibers Ltd of Ma'alot, Israel

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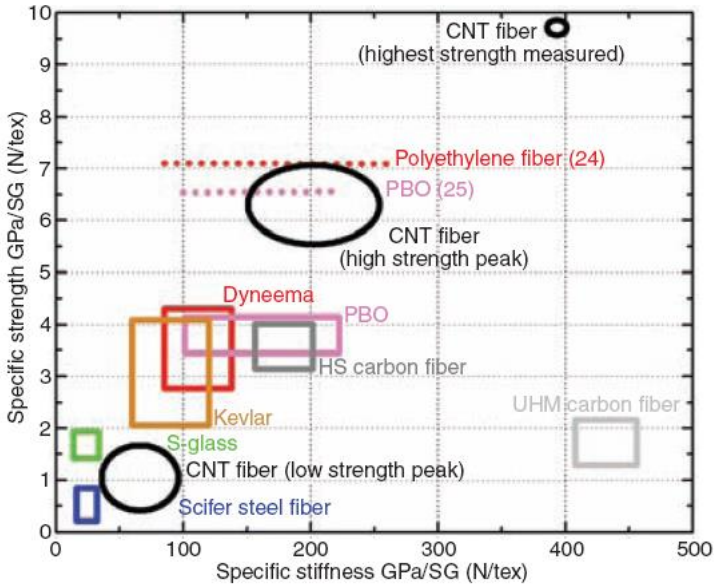
The Properties of CNT

	SWNT	DWNT	MWNT	Carbon fiber	Zylon®	Kevlar 49®
Tensile strength (GPa)		23 - 63		4 - 7	5.8	3.6 - 4.1
Tensile modulus (GPa)	640	-	1060	150 - 950	270	130
Elongation at break (%)	5.8	28	-	0.5 - 2.5	2.5	2.8
Electrical conductivity (S/m)		~10^6		5.5×10^4 - 9×10^5	< 10^{-13}	



- **Tensile strength of the CNT yarn: 8.8 GPa/SG**

  (1 GPa/SG = 1 N/tex; tex = g/1000 m)

- ❖ **Tensile Strength of Carbon Fiber(Toray T1000):**

  6.4 GPa/1.8 (g/cm^3) = 3. 6 N/tex

- **Electrical conductivity of CNT yarn: <10^7 S/m (Cu)**
- **Specific electrical conductivity of CNT yarn> Cu**
- ❖ **Carbon Fiber: 750 S/cm in Electrical conductivity**

***Science*, 2007, *318*, 1892**

Network formation of CNT fibers

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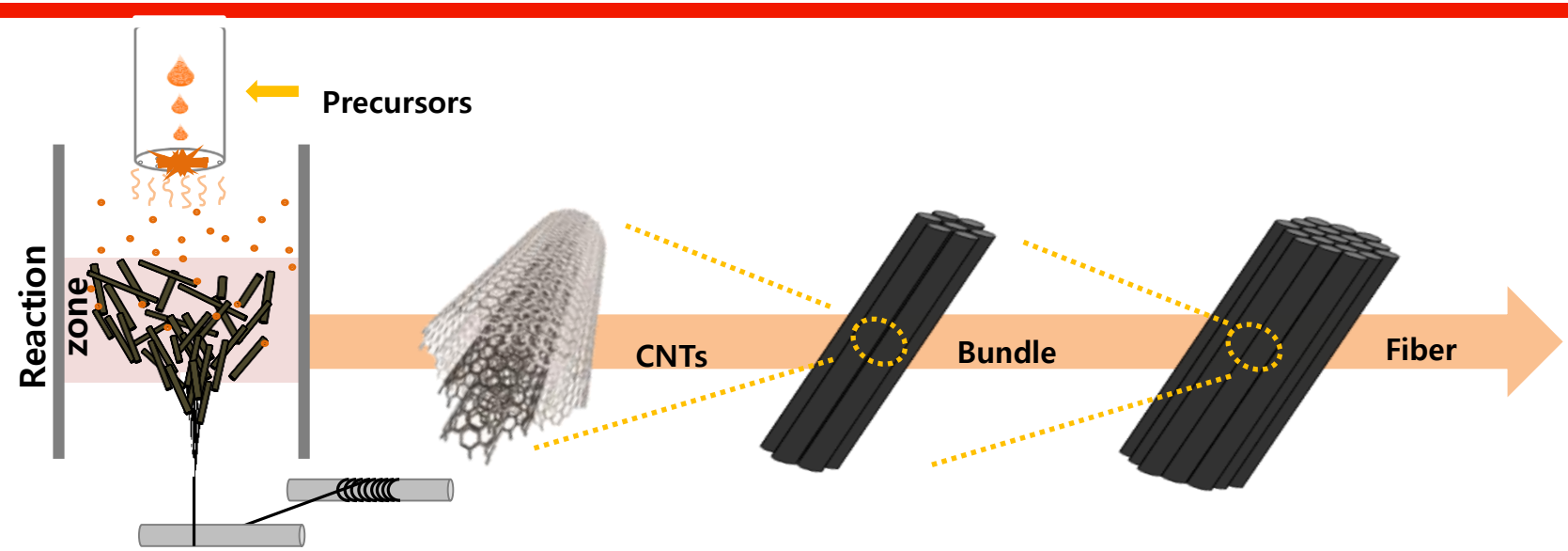
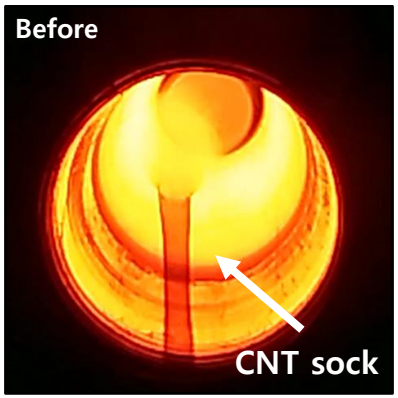
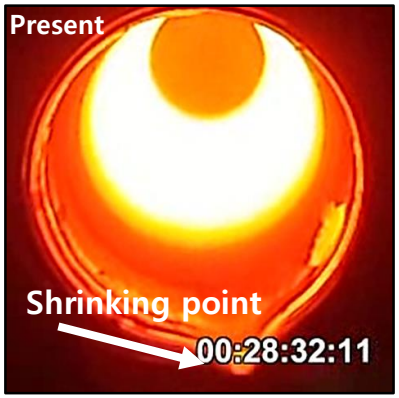
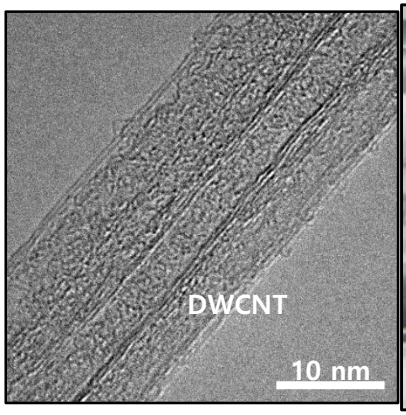
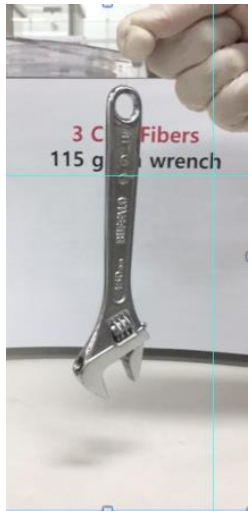


Scheme describing nanotube growth, bundling and then network formation.



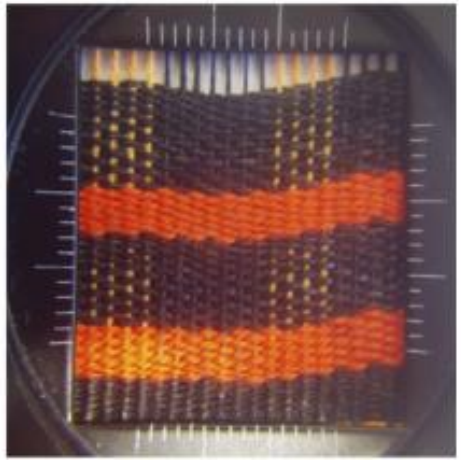






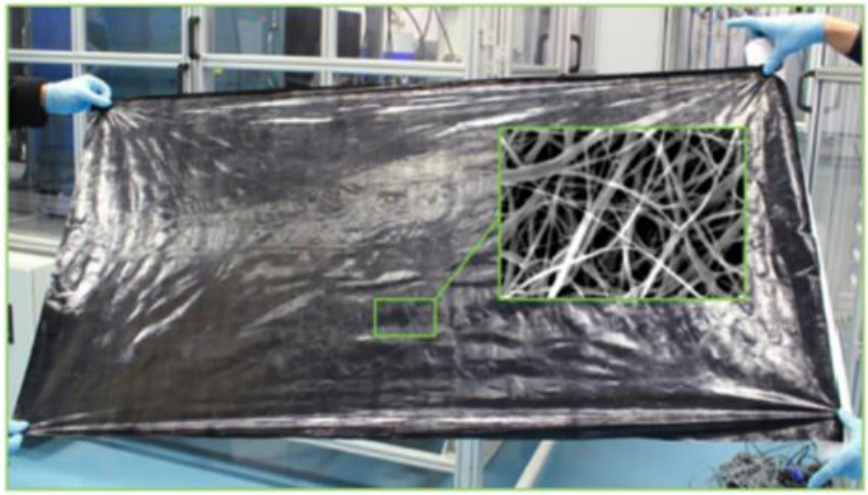
Specific strength: 0.5 N/tex, electrical conductivity: 932 S/cm

CNT composite production



Weaving with carbon nanotube thread consisting of ~300 microfibers produced by over winding on the take-up reel.

CNT films incorporated into a composite. (Courtesy Shuki Yeshuran, Tortech Nano Fibers Ltd).



CNT film with an inset showing a typical CNT structure.

- If carbon nanotube fiber is to enter the marketplace as a major player, not so much as a direct competitor for existing high performance fibers such as carbon, but as a new fiber with a unique property spectrum.
- The fiber has the potential to open up different processing routes to composites, but it also has properties which complement the baseline mechanical properties of the other fibers.

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Research Direction and Goals

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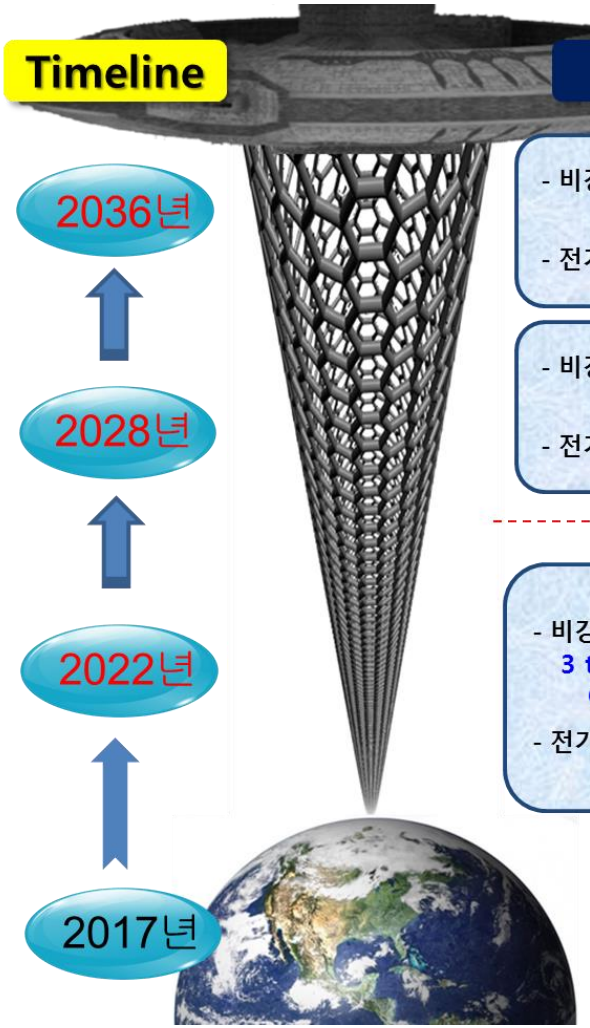


연구목표

- 비강도: **50** GPa/(g/cm^3)
  (강도: 75 GPa)
- 전기전도도: 10^8 S/m

시스템 기술

- 비강도: **40** GPa/(g/cm^3)
  (강도: 52 GPa)
- 전기전도도: 10^7 S/m

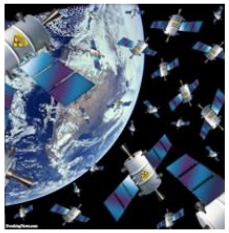
도약 기술

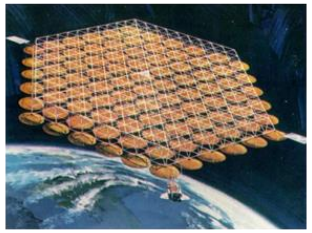
- 비강도: **10** GPa/(g/cm^3)
  3 times higher than
  CF(T1000, 3.5)
- 전기전도도: >10^6 S/m

플랫폼 기술

파급효과

인류 생존 문제 해결


핵폐기물 처리


우주 태양광 발전

고강도 탄소섬유 및 고 전도 구리 대체