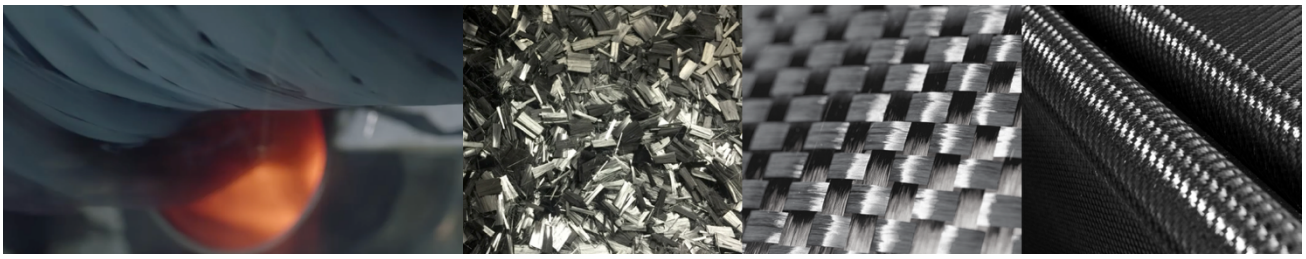
4.s02 **CARBON*HOUSE***

from Carbon*Cycle* to Carbon*Architecture*



Carbon Nanotube Furnace yielding **flocked carbon**, **woven carbon** and **tape carbon**

Syllabus *Design Seminar/Workshop*

Instructor: *Prof* **Mark Goulthorpe** (Architecture) mg_decoi@MIT.edu

Goal: Understanding the conceptual + technical elegance **Carbon** might offer architecture

Students: Open to all students (undergrad, grad, post-grad, etc)

Guests: *A broad range of carbon/composite specialists that contributed to DOE and ARPA-e* Carbon*House research will offer insight into the properties and usage of Carbon:*

Prof **Dag Olav Hessen** (carbon cycle geo-biologist), Prof **Matteo Pasquali** (CNT chemist), *Dr* **Nicola Ferralis** (carbon material scientist), *Dr* **Dave Gailus** (carbon nanotube scientist), **Dirk Kramers** (America's Cup composite structural Engineering), *Dr* **Roger Avakian** (polymer compounding), **Jeff Kent** @ *Moore Bros*, RI (composite fabrication), **Stephan Vaast** (CNC milling / composite production), *Dr* **Gus Bosse** (carbon research chemist), Dr **Steve Nolet** (wind-turbine production manager)...

Day/Time: Mon 1-4pm (informal intro Mon Feb 2, 1st Class Mon Feb 9)

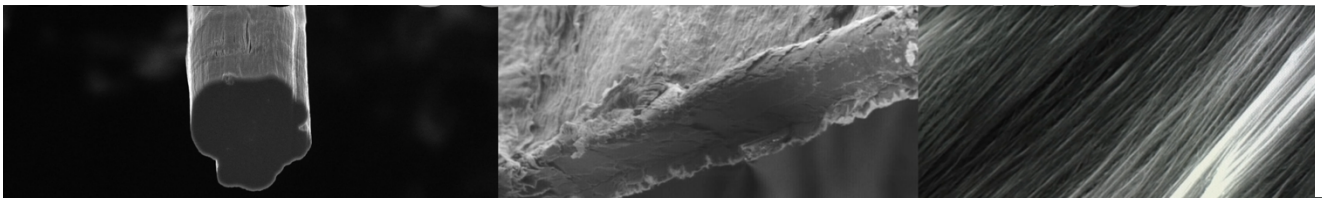
Location: **5-231**

Credits: **3-3-6** (3 hours classwork, 3 hours reading, 6 hours design work per week)

assignments can be engaged in pairs or groups with work reflecting numbers

Grading: per *MIT*/Dept guidelines, reflecting grasp of issues and aptitude in your response

Part 1 The History and Potential of ***Carbon*** *(4 weeks)*



Carbon*Nanotube* emerging morphologies of carbon elicit myriad new functional potentials…

The 6th element, **Carbon**, is *by far* the most versatile, with an atomic structure that offers virtually limitless arrangements and bonding capability: the sheer number of carbon compounds exceeds the rest of the periodic table combined. **Carbon** is of course key to *life*, two geological epochs named for the prodigious scale of biological use of carbon as its base material: the vast deposits of the *Carboniferous* (coal) and *Cretaceous* (calcium carbonate) periods. In a sense, the current *Anthropocene* is driven by (us) carbon organisms altering the balance of sequestered and atmospheric carbon (burning the organic legacy to release the energy locked-up by the almost magical capture of sunlight through billions of years of photosynthesis). The current scale of trade in fossil carbon is stupefying, oil and gas exceeding the *tonnage* of steel and cement(!), and coal perhaps equal to the total mass of building materials despite unprecedented urban and infrastructure development C21st (a *doubling* of buildings predicted by mid-century)…

Carbon bonds readily to oxygen forming **CO_2**, the *molecule of life* (and perhaps now *death*), from which plants split off their base carbon materiality from air and sunlight – a cosmic architecture! This is the basis of the magisterial **Carbon Cycle**, establishing and maintaining the O_2/CO_2 atmospheric balance that current biosystems evolved within, essentially stable for the millions of years it took for mammals to become dominant. The current disruption of atmospheric and oceanic conditions portends a perilous condition for many bio-systems, current CO_2 levels akin to those of the *Plioscene*, suiting radically different flora and fauna. Implicit within almost all environmental concern is re-establishing the **Carbon Cycle** to restore balance of solid, liquid and gaseous carbon.

Despite the ubiquity of living and fossil carbon in all global regions and its civilizational-scale natural and synthetic deployment and use, architecture has largely overlooked the potential of **Carbon** as material resource. Following *MIT/Stanford/Rice* research of the past few years, we will assimilate the various energy and life-cycle studies that offer a benign and technically sophisticated **Carbon*Architecture***, looking to deploy already-sequestered carbon into elegant, thin-skin, energy-efficient buildings, to witness a radical alternative to typical materials/methods.

Part 1 will engage Dag Olav Hessen's rueful, *The Many Lives of Carbon,* that explains the carbon cycle through eons of planetary history with a degree of foreboding. But we will diagram the majestic waltz of bio-systems in their temporal balancing of earth-/ocean-/atmospheric-carbon, with architectural sensibility, looking to capture the discordant breakdown of established bio-rhythms and its ominous portent with a speculative clarity in the hope it offers new perspectives.

Part 2 Towards a **Carbon** *Architecture*

Lear*Jet* thermoplastic tape-laying by robot

North*Sails* carbon filament tape variable curvature molded

Part 2 will turn to use of **Carbon** as a polyfunctional material, already well-established in most *other* high-performance structural applications such as boats, planes, trains, wind turbine blades, etc via fiber-based composites. The development of such materials and methods over the past 50 years has occurred hand-in-glove with emerging digital engineering and fabrication capability, with finite element

Oracle*Racing* America's Cup foiling tacing yacht

Wally*Yacht* luxury power boat using carbon composites

structural analysis essential to computing load-path in a zillion layered fibers. But it has equally been enabled by remarkable development of all manner of specialist materials such as cores, resins, adhesives, that testify to the polyvalence of **Carbon**, allowing order-of-magnitude advantage over mineral/metal structures – more akin to wood in its fibrous base-carbon morphology. The ability to orient fibers along non-isotropic stress-lines is more akin to biological systems than mechanical ones, as perhaps are the use of heat and atmospheric pressure to bind multi-material continuities.

With leading engineers and fabricators based in Bristol, RI – a pioneering center of composite fabrication – we will consider how the widespread adoption of carbon composites might now be brought to bear on **buildings**, just as le Corbusier, say, brought forward steel and reinforced concrete by considering the boats and planes of the early 20th century (in *Vers Une Architecture*).

Having absorbed the material, engineering, fabrication and environmental potentials this remarkable class of materials offers, students will be asked to envisage a **small pavilion** or a **building component** that conveys the tectonic (or anti-tectonic!) *principles* of such a Carbon Architecture, looking to capture the brilliant formal and aesthetic qualities of a potentially electro-thermal-structural new materiality. While this may speculate on emerging morphologies such as carbon nanotube or carbon foam (that hold promise of hydrogen as a corollary clean fuel, say) at issue will be to demonstrate *realism* in prescribing manufacturing methods with technical acuity.

Deliverables

The course will result in two portfolio works: the first an **exquisite diagram** of the Carbon Cycle that aims to offer graphic clarity to complex systems in a manner different from typical scientific charts, graphs and descriptions. This aims to be **inventively erudite**, capturing the essential portent of some aspect of biological and geological carbon that seems salient (to you). (NB students who have done such conceptual summary can start on *Part 2* immediately)

The second work will be a **Carbon*Pavilion*** or **Carbon*Component*** that looks to elegantly witness the potential carbon offers for polymorphous or polyfunctional deployment. Learning from boats, aircraft, wind turbine blades, trains, spacecraft… we will look to broadening the use of carbon composites "to buildings", adjusting them to meet the particular technical needs architecture requires: thermal performance, stiffness, longevity, manufacturability, cost-effectiveness, etc…

The educational goal is to develop a deep understanding of the miraculous 6th element, its vital role in earth systems, and to acquire sufficient technical knowledge to engage in its use with a degree of realism, technical erudition and design finesse. And of course, to offer a glimpse of a new **Carbon*Architecture*** that is offered as a potentially civilizational-scale alternative that may be essential to mitigate the cost and environmental footprint of typical late-industrial buildings.

Field Trip

We will visit some leading composite fabricators in Bristol, Rhode Island, looking at different scales of production, guided by Jeff Kent who pioneered the first-ever carbon fiber race boat masts. We will also get a tour of the *Herreshoff Museum*, that showcases the work of a legendary naval architect (*MIT alumni*), who remarkably beat the British in the first 6 America's Cups due to his unrelenting innovation in adopting new materials + methods, and profoundly altered boat-building.

Reading List

The Many Lives of Carbon by Dag Olav Hessen

The Material World: by Ed Conway **Oil** (chapters *The Elephant, Pipes, The Everything Thing, Peak Oil*)

Towards a New Architecture by le Corbusier

Carbon*Portal* polyfunctional exhibition pavilion to showcase structural, electrical, thermal, aesthetic properties