George P. Peterson

Recognized for…

ADVANCED COMPOSITE MATERIALS

Development and Deployment of

Advanced Composite Materials and

Manufacturing Technologies

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ADVANCED COMPOSITE MATERIALS

Outline

- Technical background
- Impacts on the materials landscape
- How it all came about…the role(s) of George Peterson

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Background

Composite Material – material composed of at least two (2) distinctly different materials acting in concert

Reinforced Composite Material – a composite material consisting of reinforcing fibers, whiskers, and/or particles in a common matrix binder

Advanced **Composite Material – a reinforced composite material containing high performance (advanced) reinforcing fibers – Boron (B), Carbon (C) - in a suitable structural matrix resin**

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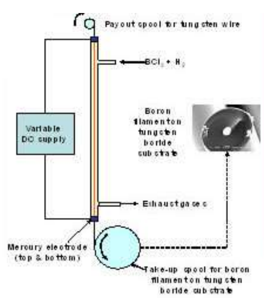
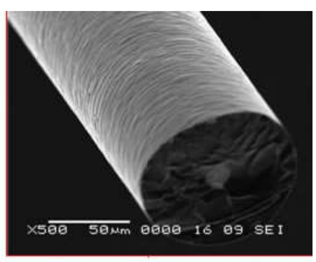
Advanced Composites… distinguishing features:

- **Exceptional mechanical and physical properties**
  - **high *moduli* and strength**
  - **low density**
  - **high volume loading of fibers**
- **Anisotropy (properties are directionally dependent)**
- **Tailorability**

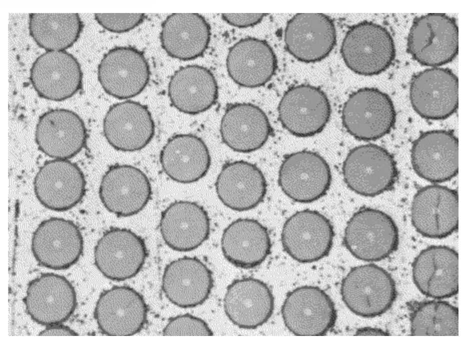
BORON (B) FILAMENTS





Continuous, High Modulus and Strength Filamentary Reinforcements

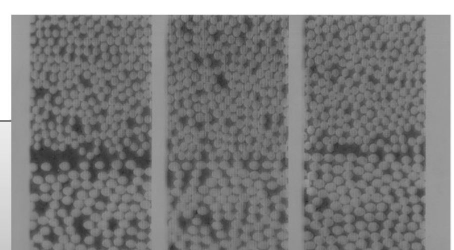
Process: CVD of boron on a tungsten filament substrate



Boron Filament Reinforced Composites

CARBON (C) FIBERS

Continuous, High Modulus and Strength Fiber Reinforcements



Process: pyrolysis of a polymeric precursor to a carbonaceous/graphitic material

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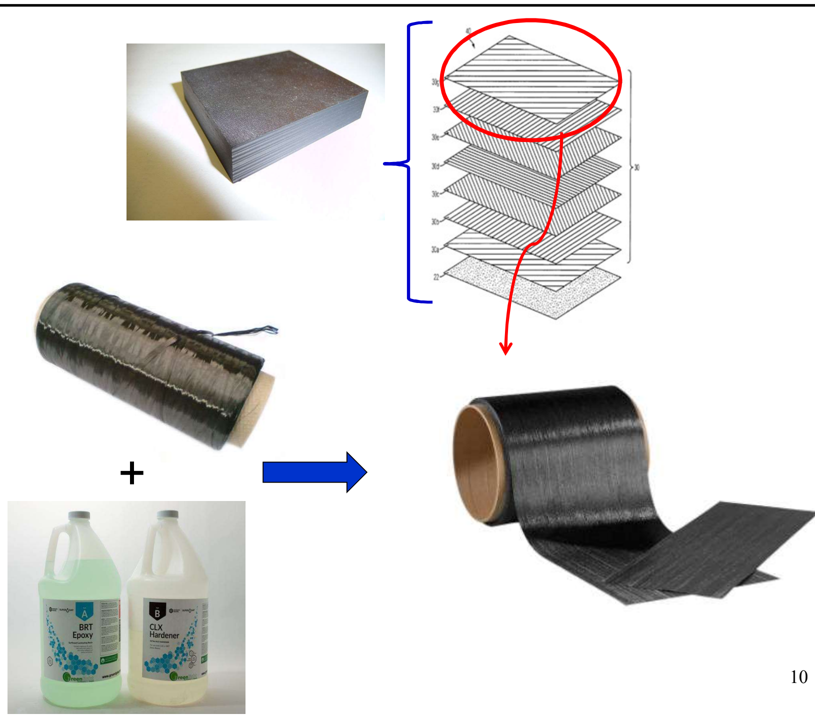

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Why Composites?

- **High Strength-to-Density**
- **High Stiffness-to-Density**
- **Formable to complex shapes**
- **Nonconductive/conductive**
- **Corrosion resistance**
- **Fatigue resistance**
- **Creep and stress rupture resistance**
- **Controlled (low) thermal expansion**
- **Lower cost**

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Major Advantage – Specific Properties

Specific Property = property/density

Higher *Specific* Strength → **Weight Savings**

Higher *Specific* Modulus

Weight Savings → **More efficient structures**
Reduced energy costs
Reduced materials costs

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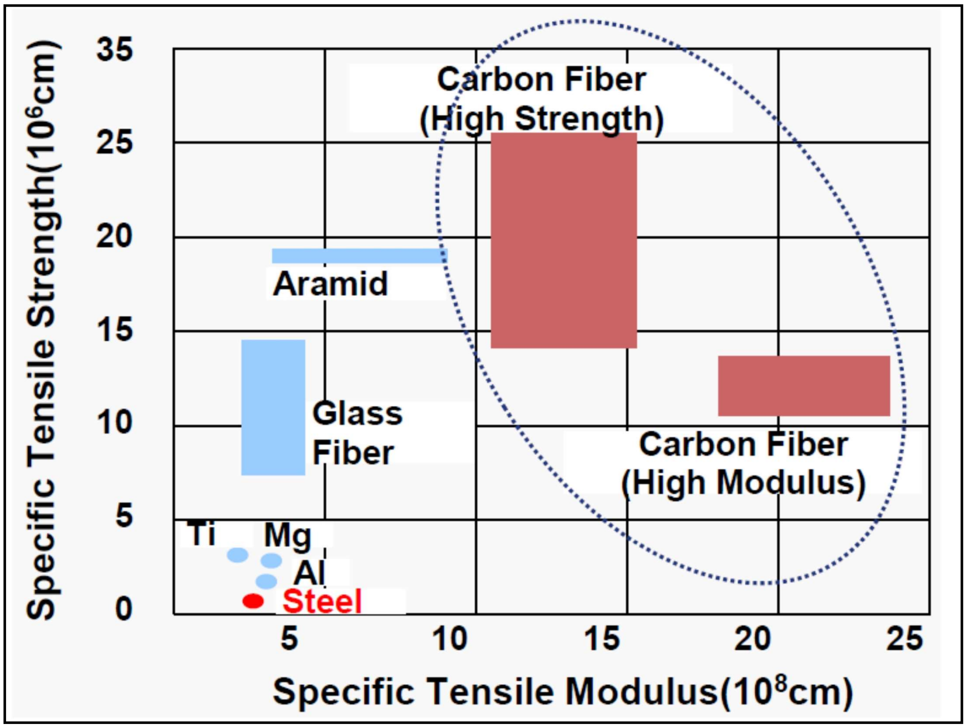

Two major factors driving materials properties:

- **Bonding**
- **Morphology**

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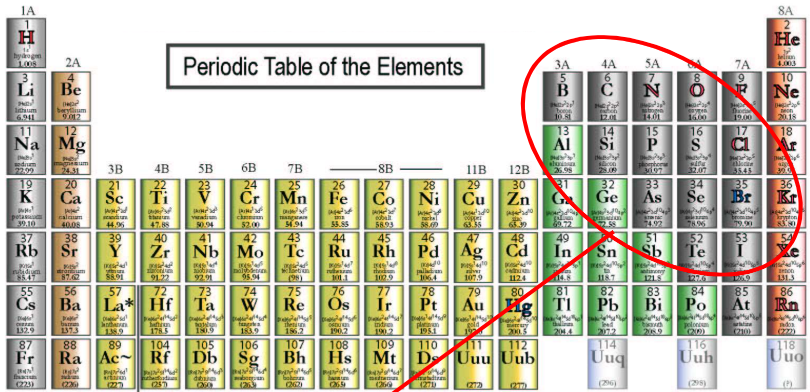
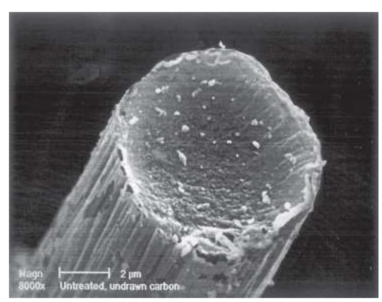


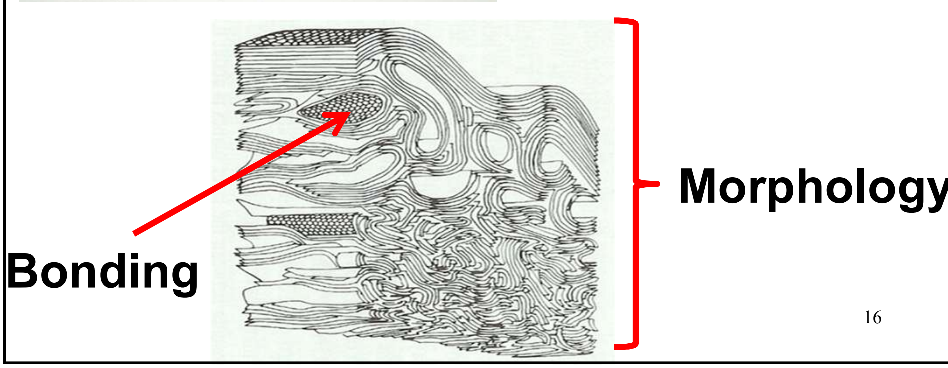
Compounds from these elements are candidates for

- o lighter
- o stiffer
- o stronger
- o thermally stable

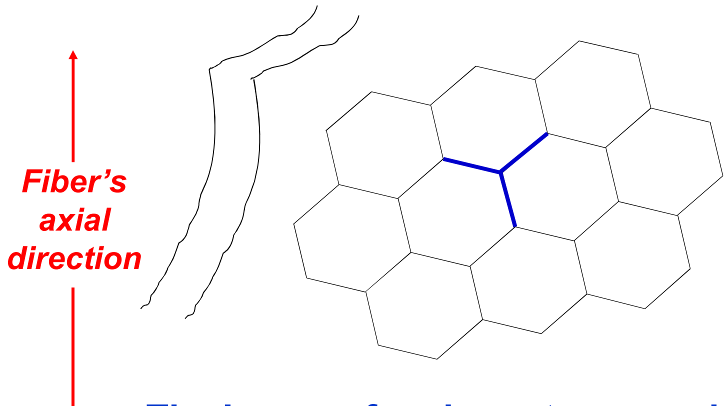
materials. Most are relatively light and form thermally stable ***covalent bonds*** (key property) which are **inherently stiffer and stronger** than compounds formed from metallic or ionic bonds. Further, most are abundant and ***potentially*** inexpensive. They are **usually only useful in fibrous form** because it minimizes the presence of internal flaws which detract from the ultimate strength of the homogenous material.

Structure of carbon fiber





Proposed Formation of a Ribbon-like Structure



The layers of carbon atoms are in a hexagonal arrangement with ***covalent bonding*** between atoms

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Advanced Composites…1970


Aerospace…2019

Sporting goods…2019

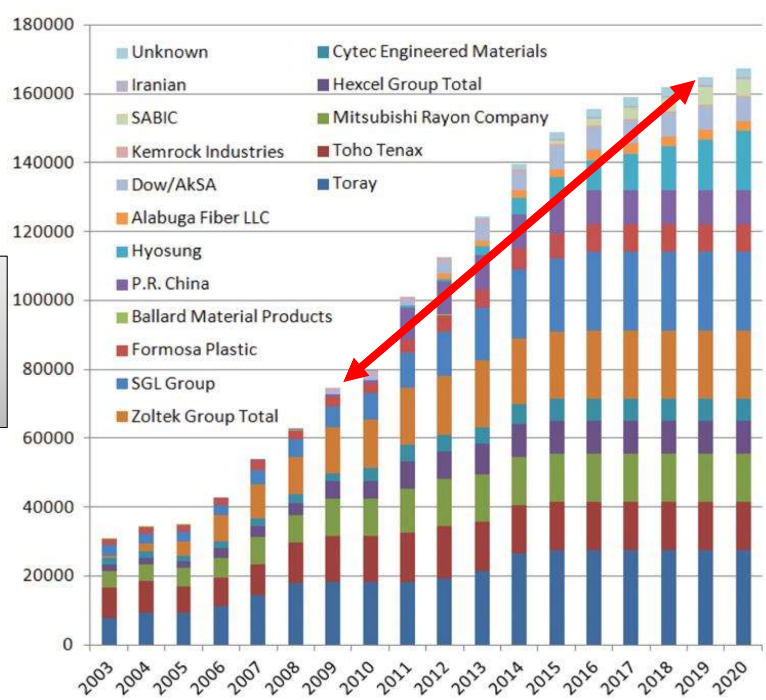
Infrastructure…2019

Transportation …2019

Medical…2019

Energy…2019

Carbon Fiber Capacity in metric tons



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Context: *1960s/1970s technology climate*

- **Very limited characterization tools**
- **No mechanical analysis tools for anisotropic laminated materials**
- **No nondestructive investigation tools such as ultrasonic inspection**
- **No standard test methods for composite materials**
- **No text/reference books**
- **Computers in their infancy**
  - **No computer controls**
  - **No modeling**
  - **No internet!**
  - **No Google!**
- **Yes…no cell phones!**

Context: *1960s/1970s*
revolutionary materials "insertion" *climate*

- Early Performance values must be compelling
- Resources are a must
- Major *risk taking* required
  - Limited technology climate
  - Preliminary data may not be adequate to assess potential
  - Initial manufacturing may be "hands on"
  - Future processing methodologies may need to be invented
  - Maturity time unknown
  - Initial applications may be limited

Given this context, how did a new materials technology evolve?

The Answers…

Compelling properties
Champions
Vision
Resources
Risk takers
Creative leaders and engineers

"Game Changers"

"game changers"

… "events" which had a profound, long lasting impact; changed how these materials were used, analyzed, evaluated, processed….

Early Game Changing Events

- Project Forecast I
- Primer
- Data programs
- Advanced Comp Design Guide
- Fibers
- Fabrics
- Resins/matrices
- Tape
- AF Mantech programs….
- Early automation
  - Filament winding
  - Tape machines
  - Tape placement machines
- Producibility programs
- Machining methods…drilling, cutting….
- Initial Demo/Production Parts
  - F-14, F-15, F-16, B-1 (1.0)
  - RR fan blade
- Processing science
- Quality
  - NDI
  - Chemical QA
- The "problem" era
  - Moisture problem
  - Fiber release
  - Galvanic corrosion
  - Lightning strikes
- Test methods/stds
- Repair methods
- Durability/damage tolerance
- Cure monitoring programs
- The "toughness" era
  - Themoplastics…toughened epoxies
  - Boeing spec, open-hole compression
  - Free edge
  - Mode I
  - Hydrodynamic ram
- The Clinton years

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PROJECT "FORECAST" (1963)

- first major Air Force planning initiative focusing on materials…
- to identify and promote enabling technologies for revolutionary advances in U.S. aerospace capabilities…
- recognition of the potential of "the boron filament and *composite* materials efforts"…

Advanced Composites Program

Key Elements of the Advanced Composites Program (1963)

- Long range plan
- Resources
- Organizational framework
  - Leadership at all levels
  - High performance teams
  - Creativity
  - Flexibility
  - Customer focus

Key Elements of the Advanced Composites Program (1963)

Organizational framework – *GPP's leadership roles*

- 1964 - Advanced Filaments and Composites Division
  - *Chief: GPP*
- 1967 - Advanced Composites Division
  - *Chief: GPP*
- 1971 - Composites Recast…*GPP leadership position*
- 1972 - Advanced Development Division
  - *Chief: GPP*

- 1972 – Manufacturing Technology Division
  - *Chief: GPP*
- 1975 – AFML
  - *Director: GPP*

Key Elements of the Advanced Composites Program

The organizational framework, leadership positions of GPP, and the "state of the technology" perfectly meshed.

Game Changing Events

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George Peterson's Technology Legacy

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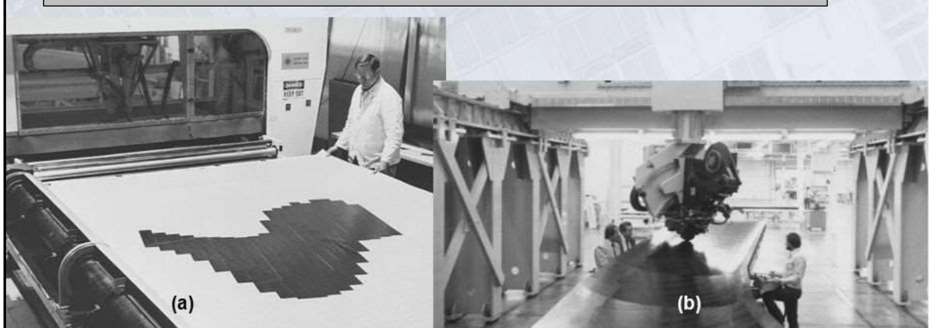
AF Mantech Programs….

….The Rise of the Machines….

…Brought automation to advanced composites manufacturing

Early Manufacturing

First Generation *Tape* and *Automated Tape Laying* Machine



B/Ep tape
F-14 (F-15) Parts
Grumman - Ingersoll

Latest generation *Automated Tape Placement* Machines

George P. Peterson

- **Visionary leader**
- **Tireless advocate**
- **The consummate champion**

…for a revolutionary materials technology – Advanced Composite Materials