Carbon Fiber Supply and Demand

Supply of PAN based carbon fiber

New players could make all the difference

San Diego, California, USA
October 23 2007

The ongoing shortage of PAN based carbon fibers has seen the planning, development and realization of new carbon fiber manufacturing capacity in new countries.

The start up of new plant faces many hurdles, especially in the face of competition that has been in the business for many decades.

However these hurdles have been overcome and this process will enable carbon fiber to become truly a commodity product, available to the vast range of current and new composite applications.

Latest News

(Press releases in the last 4 weeks)

Supply

October 11, 2007 Capacity Expansion of Carbon Fiber "TENAX®"

Toho Tenax Co., Ltd. (Head Office: Bunkyo-ku, Tokyo, President: Yoshikuni Utsunomiya), which is engaged in the business of carbon fibers within the Teijin Group, has decided to add a new carbon fiber production line at Toho Tenax Europe GmbH (located at Wuppertal, Germany.

October 05, 2007 SGL Group plans to triple carbon fiber capacities

SGL Group plans to triple carbon fiber capacities
Capacity increase up to 12,000 metric tons by 2012

Demand

September 27, 2007 British Airways Green light for aircraft orders

British Airways has today placed an order for 12 Airbus A380 and 24 Boeing 787 aircraft with options for a further seven Airbus A380s and18 Boeing 787s.

The British Airways Order

The new aircraft will replace 34 of the airline's long haul fleet and will be delivered between 2010 and 2014. The order, including options, will give the airline the ability to grow its capacity by up to four per cent per year and the flexibility to tailor its future capacity growth in line with market conditions.

The aircraft will be greener, quieter and more fuel efficient with significantly lower carbon dioxide emissions and reduced impact on local air quality. This was a key consideration in the order.

Willie Walsh, British Airways' chief executive, said: "This is an exciting day for British Airways with our largest fleet order since 1998. It's great news for our business, our customers and the environment.

"These aircraft set the gold standard when it comes to environmental performance in the key areas of CO2 emissions, local air quality and noise. They will contribute significantly to our target of improving fuel efficiency by 25 per cent between 2005 and 2025."

Carbon Fibers in 2007

Replacing traditional materials with products of outstanding performance.

Finding ever new applications as varied as aircraft to designer furniture.

Despite huge increases in capacity still demand outstrips supply.

~~April~~ October 2006 Demand and Supply Situation

2007

From website www.carb.com

(typical of many carbon fiber users)

URGENT NOTICE!

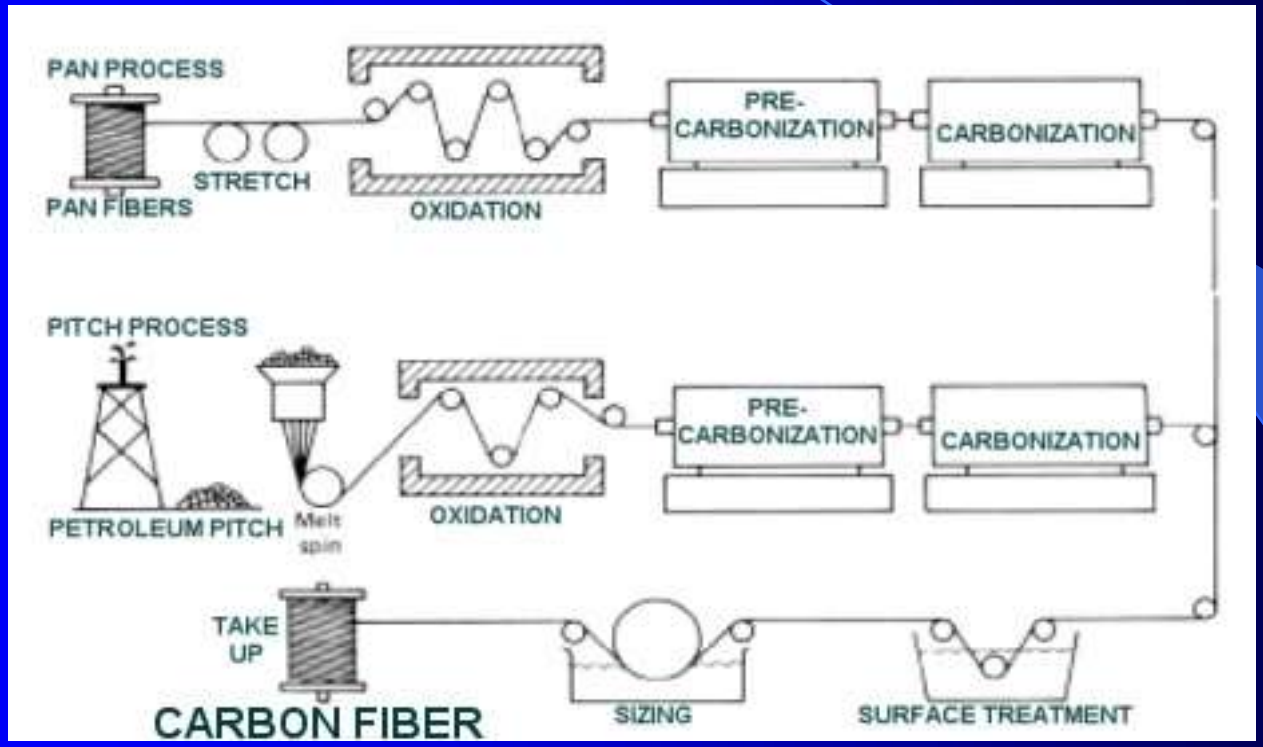
Due to the severe global shortage of carbon fiber, and in order to continue shipping SOME carbon fabric to our customers, Carbcom will be limiting purchase quantities and temporarily eliminating bulk pricing.

We deeply apologize than Carbcom cannot be the aggressive price leader we have been up until recently, and we hope in the future you will buy larger quantities again when we are able to secure the volume of fibers we need to serve you with full shipments at great pricing!

Toll-free 1-888-CARBCOM / (888-227-2266)

International call: 1-808-579-8000

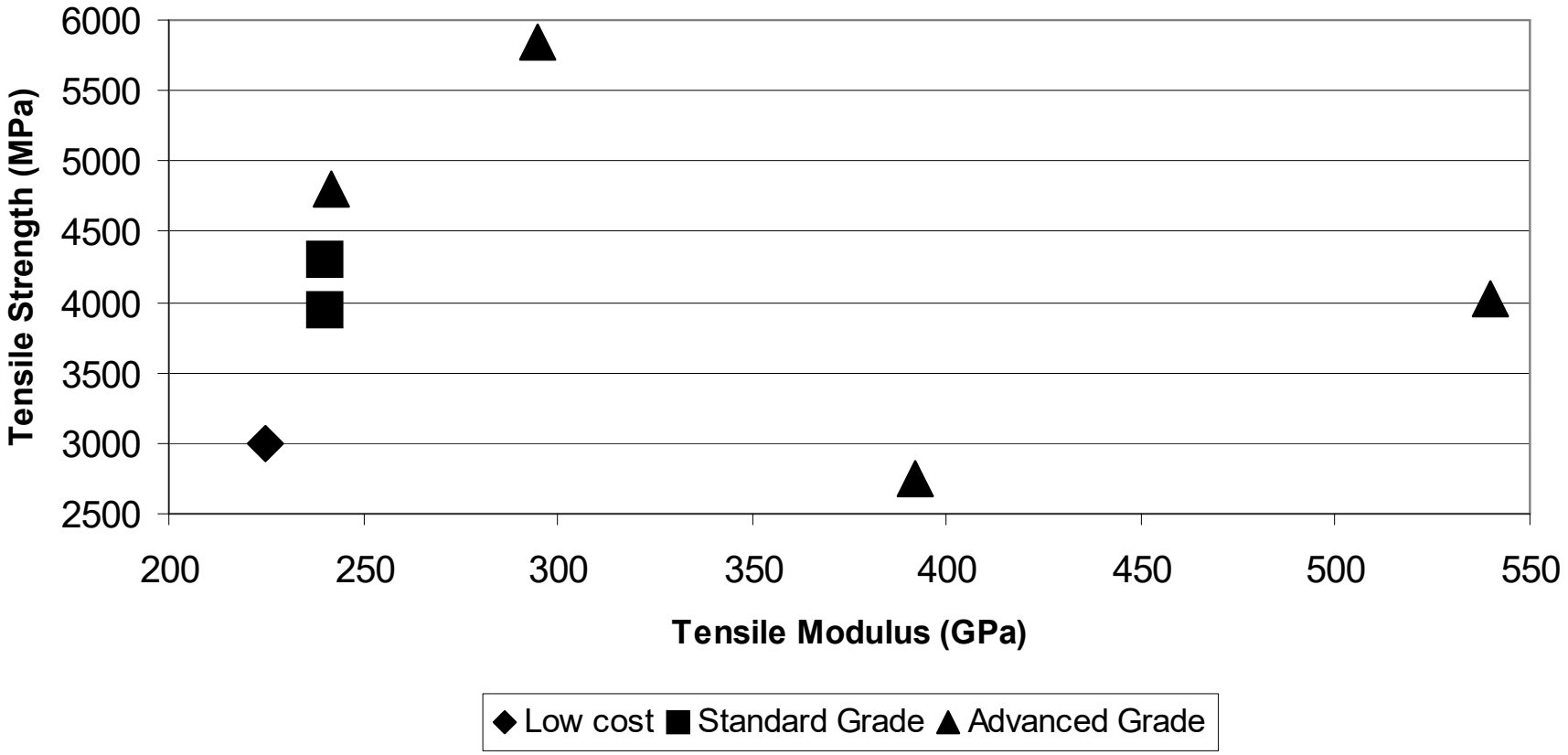
Manufacture of Structural Carbon Fibers
PAN / Pitch processes



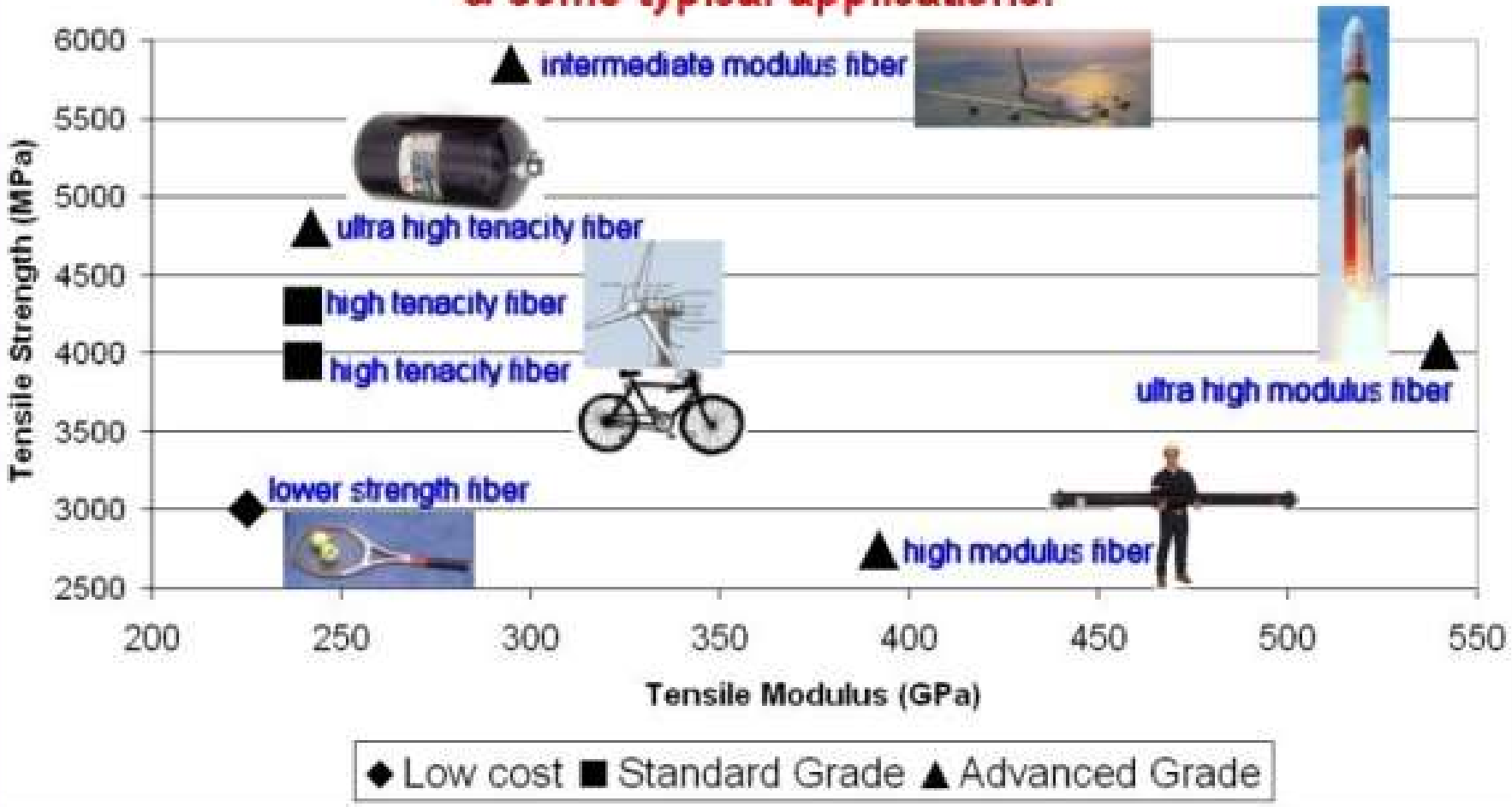
Pitch = cheap, lower tensile strength

PAN= more expensive, superior properties

Mechanical Properties of PAN based Carbon Fibers

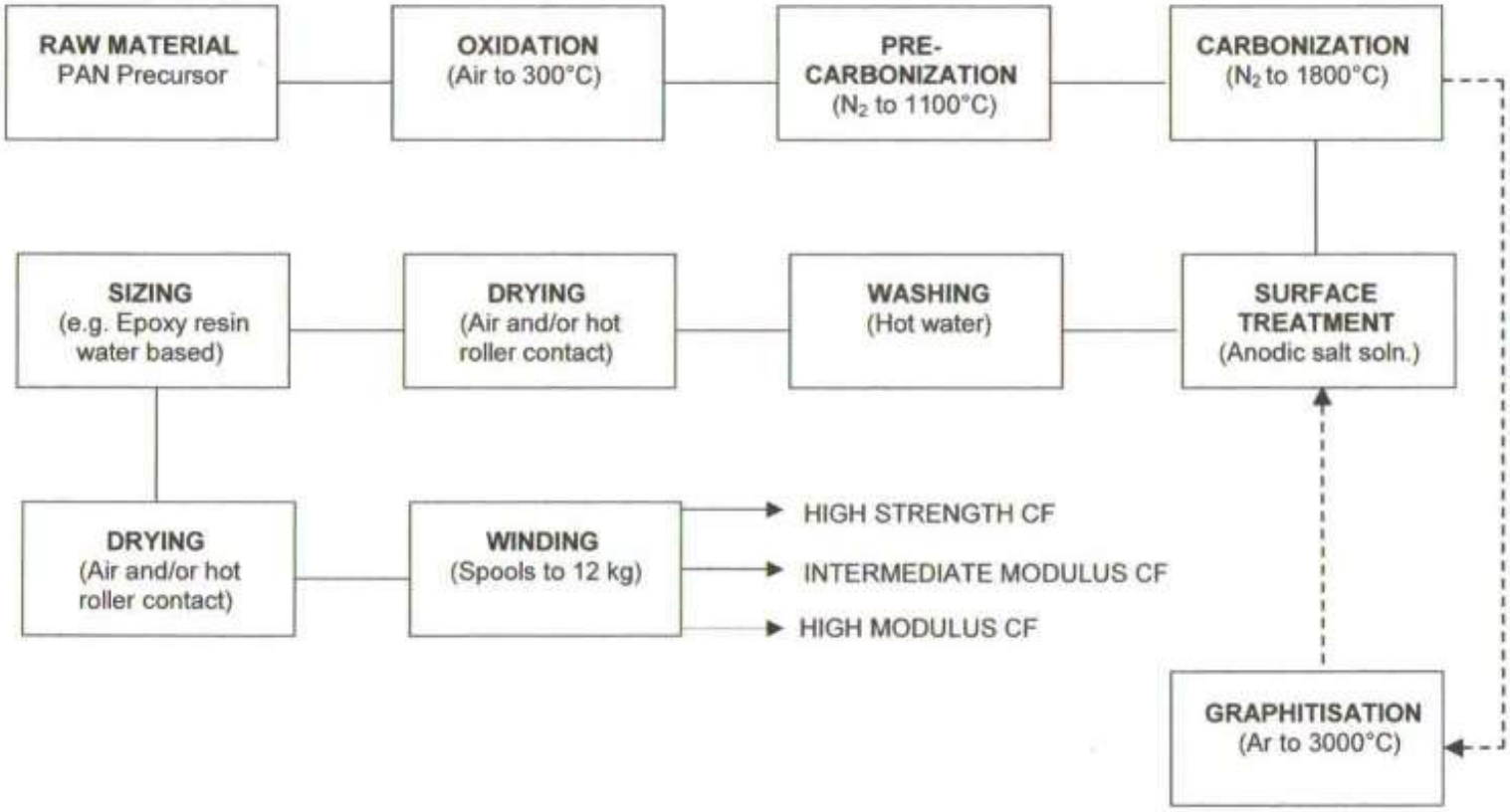


Mechanical Properties of PAN based Carbon Fibers
& some typical applications.



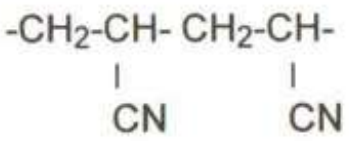
Vince Kelly Global Outlook for Carbon Fiber 2007 www.carbon-fiber.com

Process flow for the manufacture of PAN based carbon fiber



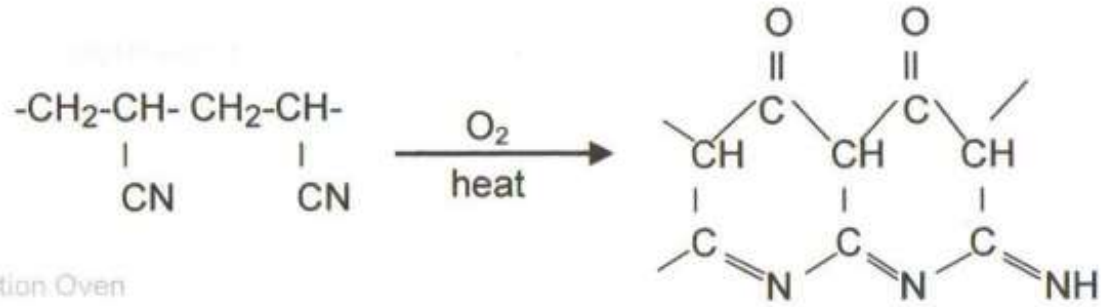
Vince Kelly The PAN Carbon Fiber Process www.carbon-fiber.com

RAW MATERIAL
PAN Precursor



- Specially developed PAN (**P**oly**A**crylo**N**itrile) fibers for the carbon fiber industry, using traditional technologies of acrylic textile fiber manufacture.
- Most carbon fiber companies manufacture their own precursor, using in house technologies. Variables include type of solvent, type and amounts of co-monomers, degrees of fiber shrinkage and stretching in the manufacturing process.
- For high performance carbon fibers, the fibers are collected in bundles of 1000 (1K) to 24000 (24K) filaments. The bundle of filaments is commonly referred to as a "tow".
- PAN tows are usually supplied on spools of up to 50kg weight. These are placed on a precision creel to allow one tow to run next to another to make a towband or sheet of tows, which are transported through the carbon fiber process.
- For the manufacture of lower grade carbon fiber, some commercial textile acrylic fibers are supplied in boxes of up to 300kg weight. These contain a continuous crimped sheet of up to 350000 filaments. Several of these "heavy tows" are transported together though the carbon fiber process in a towband. Not all commercial textile acrylic fibers are suitable for conversion to carbon fiber.

OXIDATION
(Air to 300°C)



+HCN, CO_2, Δheat

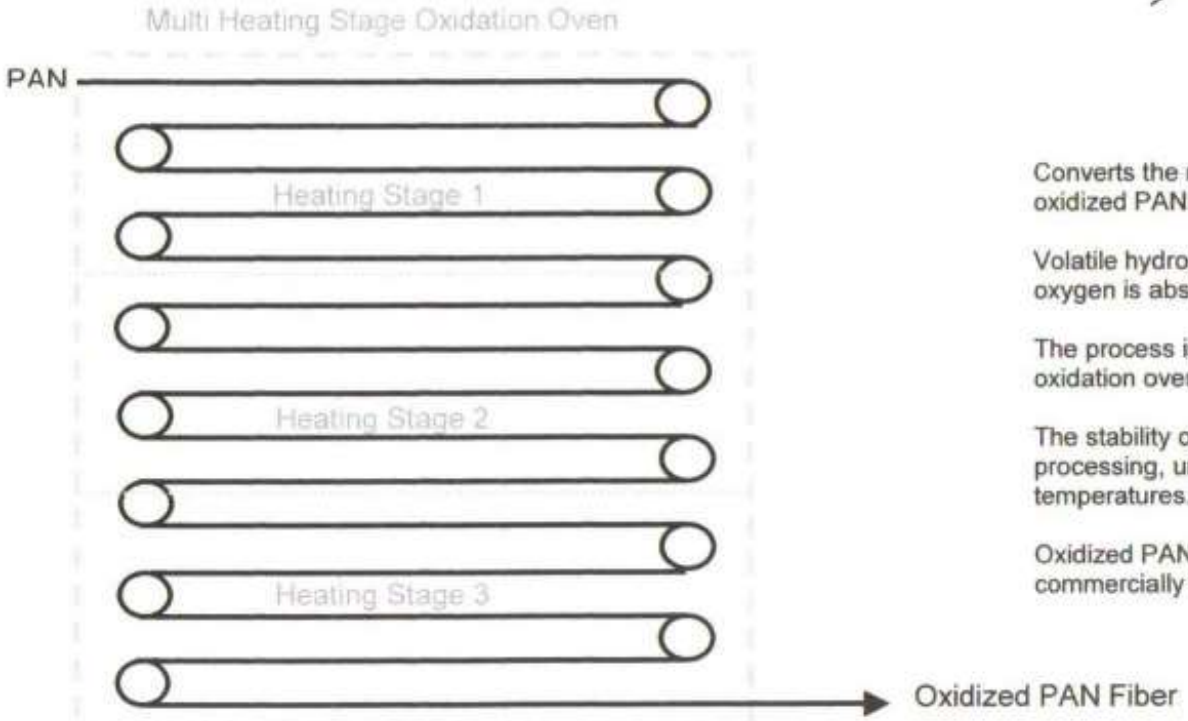
Converts the molecular PAN ladder, to the stable oxidized PAN ring structure.

Volatile hydrogen is evolved and less volatile oxygen is absorbed into the ring structure.

The process is extremely exothermic, fires in oxidation ovens are not uncommon.

The stability of the fiber allows further processing, under Nitrogen to higher temperatures.

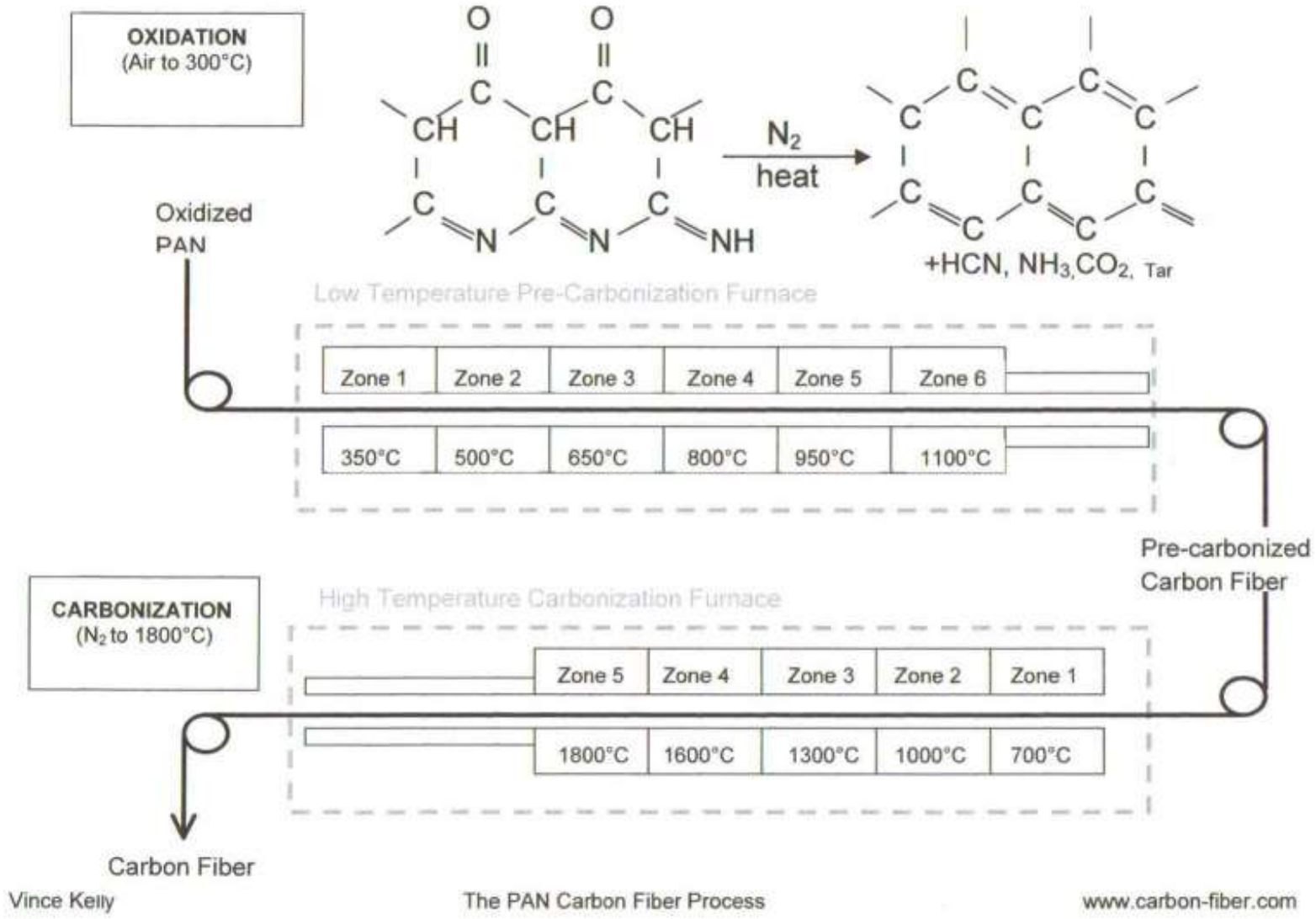
Oxidized PAN is flameproof and is produced commercially as a fire resistant textile fiber.



Vince Kelly

The PAN Carbon Fiber Process

www.carbon-fiber.com


OXIDATION
(Air to 300°C)
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C
C
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C
C
C
C
C
+HCN, NH_3,CO_2, Tar
Oxidized
PAN
Low Temperature Pre-Carbonization Furnace
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
350°C
500°C
650°C
800°C
950°C
1100°C
Pre-carbonized
Carbon Fiber
CARBONIZATION
(N_2 to 1800°C)
High Temperature Carbonization Furnace
Zone 5
Zone 4
Zone 3
Zone 2
Zone 1
1800°C
1600°C
1300°C
1000°C
700°C
Carbon Fiber
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The PAN Carbon Fiber Process
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PRE-CARBONIZATION
(N_2 to 1100°C)

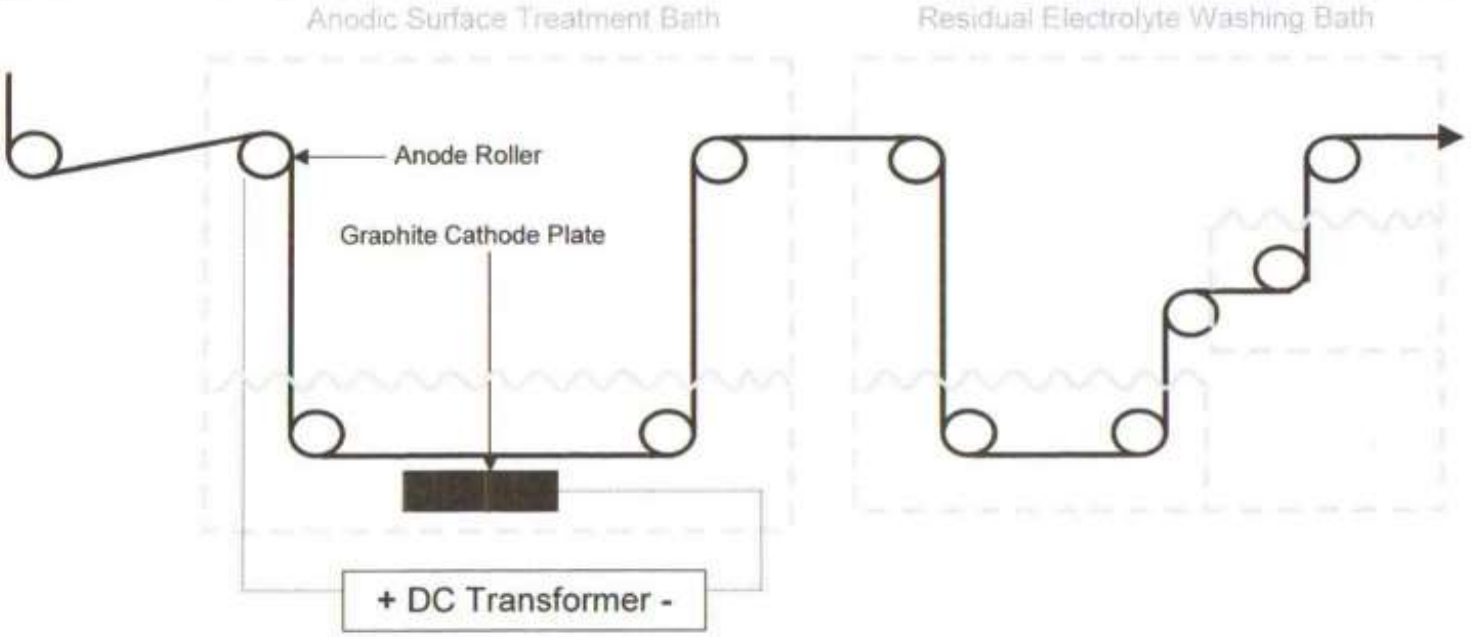
- Oxidized PAN fiber pass through the metal muffle of a furnace, multi-zone heated up to 1100°C.
- Weight loss of up to 50% of the ingoing fiber occurs. The gasses evolved are mainly compounds of cyanide, which forms tarry gasses, which are incinerated directly after exhaust from the furnace.
- Roller drives before and after furnace enable a specific, stretch or shrinkage to be set in the process.

CARBONIZATION
(N_2 to 1800°C)

- The product exiting the pre-carbonization furnace is a low quality carbon fiber. Further processing in the carbonization furnace, induce the properties of strength, modulus, electrical conductivity and fiber density.
- Pre-carbonized fiber pass through the graphite muffle of a furnace, multi-zone heated up to 1800°C. The conditions in the (pre) carbonization process can be varied for the manufacture of high strength and intermediate modulus carbon fiber.
- For high modulus carbon fiber a third heat treatment in Argon up to 3000°C is used.

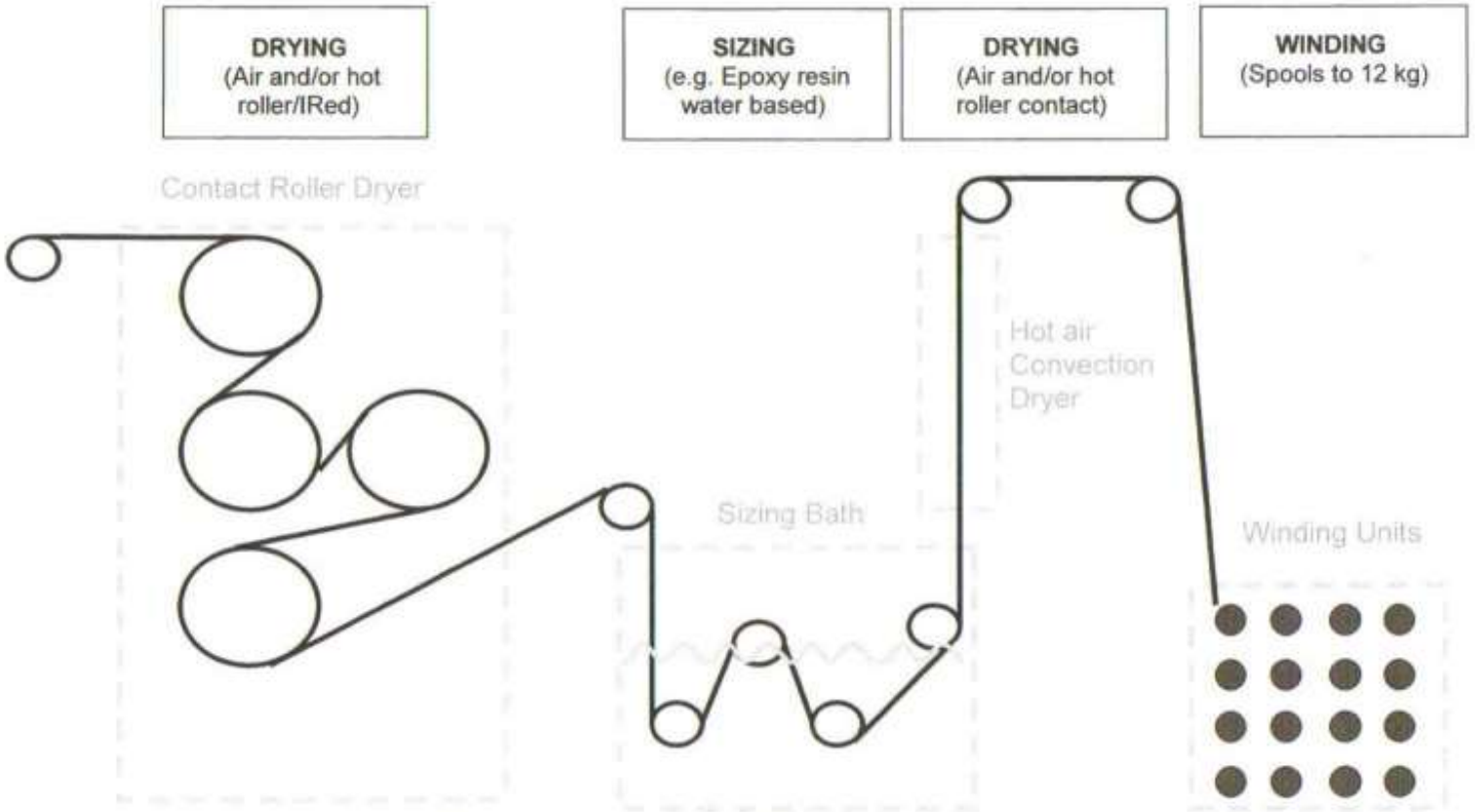
SURFACE TREATMENT (Anodic, salt soln.)

WASHING (Hot water)



- The electrically conductive carbon fibers become the anode in electrolysis in a salt solution such as ammonium sulfate.
- This causes carboxyl groups such as COOH to form on the smooth fiber surface.
- The carboxyl groups improve the cohesion between the fiber and the resin used in the final composite.

- After surface treatment excess electrolyte is removed by a warm water wash treatment.
- The carbon fiber strands pass through one or more dip baths, with counter current water flow.



- Carbon fiber strands are pre-dried prior to sizing. This helps ensure a uniform "pick up" of sizing.
- A typical sizing is a dispersion of water and small epoxy particles. The water is dried off, to leave the filaments coated in an epoxy film. This enables ease of handling during further processing of the fiber (e.g. prepregging). Non, and modified epoxy sizings are available for specialist applications. Winders can produce finished spools of up to 12 kg in weight.

Raw Material for PAN based Carbon Fiber: Acrylic Fiber

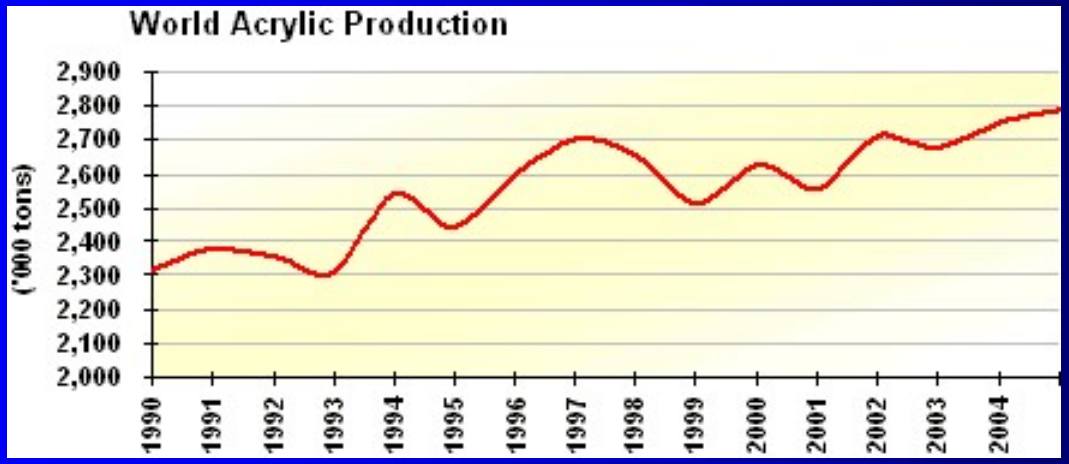
Definition:

A synthetic fiber of which at least 85% is acrylonitrile (vinyl cyanide) and the remaining is some other vinyl compound. Orlon was the first acrylic fiber to be developed. Acrylic is produced in staple form and is spun on both the woollen and worsted systems. Acrylics have a wool-like handle and are used for knitting yarns.

Raw Material for PAN based Carbon Fiber: Acrylic Fiber

World Capacity:

Steady growth since 1990. Currently thought to be over 3000 000 TPA in 2010 production could reach near 4000 000TPA



Raw Material for PAN based Carbon Fiber: Acrylic Fiber

What is current PAN based carbon fiber demand?

Steady Demand in 2010 is anticipated to exceed 40,000 TPA

How much acrylic fiber do we need for that?

For 40 000 TPA carbon fiber, will produce around 90 000TPA acrylic fiber precursor

So if acrylic fiber production is 4000 000 TPA we can easily increase carbon fiber capacity right?!

No! The vast majority of acrylic fibers are unsuitable for conversion to carbon fiber. This is mainly due to additives and co-monomers added to improve their performance in textile applications. However these hinder the thermal conversion required in the carbon fiber process.

How can new manufacturers of carbon fiber get suitable acrylic precursor?

Develop the precursor "in house"

This route is thought to be happening in the PRC with assistance from educational institutes such as Beijing University.

Current acrylic manufacturers develop some of their production for carbon fiber precursor

It has been announced that this is happening at AKSA, in Turkey. Their site at Yalova near Istanbul has a capacity of 250 000 TPY of acrylic fiber

Convert redundant acrylic fiber plant to precursor production

Former Acordis acrylic fiber plant at Kelheim Germany. "Austria's Lenzing Group is expanding into the production of carbon fiber with the proposed formation of a joint venture – European Precursor GmbH – between its subsidiary Lenzing Plastics GmbH and two German partners—SGL Carbon AG of Wiesbaden and Kelheim Fibers GmbH from Kelheim."

Bluestar Fibers, Grimsby, UK

BLUESTAR
Bluestar Fibres Company Limited

History

Former home of Courtelle acrylic fiber. This textile fiber could also be used as carbon fiber precursor. Courtelle was used by Zoltek (since acquired their own acrylic fiber company in Hungary) and SGL (currently looking at the European Precursor GmbH in Kelheim and Fortafil Fibers (since taken over and supplied by Teijin-Toho Tenax.)

The Grimsby plant was finally acquired, after a failed management buy-out, by the China National Bluestar Corporation.

Bluestar Fibers, Grimsby, UK

Bluestar Fibers, Grimsby, UK

BLUESTAR
Bluestar Fibres Company Limited

Present Situation

Bluestar Fibers in Grimsby UK have a capacity of 80 000 TPY of acrylic fiber available for conversion to carbon fiber. The company concentrates purely on carbon fiber precursor and sells to the open market.

Conversion of all precursor from this one facility would double global PAN based carbon fiber capacity!

New Capacity – Where?

With free supply of precursor, new carbon fiber plant capacity could be built almost anywhere.

Current carbon fiber plants for example in Japan, France, Germany and the USA are not in low cost labor countries.

This low volume high value business is ideal for smaller countries such as Iceland and Ireland.

New Capacity: Supply of carbon fiber production plant

This will be dealt with in the second part of the presentation.

Thank you

Vince Kelly