THE CHEMISTRY OF MODERN SPORTS

Veena Patwardhan, Special Correspondent

Chemistry is revolutionising sports like never before. Advances in chemical and materials sciences have phenomenally changed sports, games and sports fields so much so that the Olympic motto, 'swifter, higher and stronger' has acquired dimensions unimaginable a few decades back. Chemistry, as always, is the behind the scenes player, the back end performer for front end performance, unaware to most people, helping sportspersons perform better and transforming the very nature of modern sports.

Read this fascinating account of chemistry's role in sports, the link between benzene rings and Olympic rings.

What's the bond between chemistry and sports? What's the link between benzene rings and Olympic rings? For many people, including sports enthusiasts, it may come as a surprise that today's sports gear, apparel and field surfaces are, for the most part, chemical marvels.

For instance, how many know that when the legendary sportsman Lance Armstrong won a record-setting sixth victory in the strenuous Tour de France bicycle race in 2004, despite his exceptional talent, he didn't achieve this all on his own? Chemistry was his secret helper. The bicycle he rode was a hi-performance one custom designed to be lightweight yet capable of providing the necessary stiffness and strength for negotiating the 21 zigzagging switchbacks of the Alpe d'Huez stage of the race. The frame and other components were made from composites and the bicycle weighed in at a mere 14.99 lbs, the minimum permitted under international rules.

But not just bicycling, chemistry is revolutionizing almost every sport. Sportspersons and athletes expect continual enhancement in the performance of their sporting gear and chemical technologists have risen to the challenge by improving their design as well as incorporating innovative materials. The materials that have found the maximum applications in the sports arena are carbon fibre composites. Carbon fibre is a high strength, low weight, corrosion-resistant material because of which it is often used as an ideal substitute for metal. Carbon fibres are also very versatile in that a wide variety of composites can be made from them, for instance, a carbon fibre/epoxy composite is used for making bicycle frames.

Some of the other hi-tech materials used to tweak sports paraphernalia include fibreglass composites, polyurethane, thermoplastic polyurethane, polycarbonates, polyethylene, polypropylene and polymer hybrids.

Sports Equipment

The impact of chemistry is most evident in sports that call for specialized equipment. Such products are constantly being modified through innovations, which is why sports gear in use today is not the same as it used to be. Take for instance golf clubs which around four decades ago had aluminium or steel shafts, whereas today composite fibres or polymers are used in the shafts to propel golf balls at much higher velocities. Also, heavy wooden tennis rackets are a thing of the past. These are now made out of carbon fibre composites and are lighter, sturdier and more resistant to cracking. The wooden hockey sticks of old are replaced by sticks made of lightweight aluminium with titanium inserts. Similarly, squash and badminton rackets, fishing rods, ski poles, poles for vaulting, tent poles, softball/baseball bats, bows and arrows, fishing rods and marine hulls have all benefited from the high-performance characteristics of carbon fibre composites.

A combination of the characteristics of the different components gives composites superior qualities as compared to any homogeneous material such as metal. For example, different types of golf shafts are made by using different ply thickness, and carbon fibres having different orientation and tensile modulus. Modern pole vaulting poles are made out of carbon fibres and fibreglass for added flexibility and strength, while at the same time making them lighter and therefore easier for the athlete to manoeuver. For making the frame of racer cycles like the one used by Lance Armstrong, carbon fibres impregnated with epoxy are placed inside the frame mould. In ice hockey sticks, a mix of different carbon fibres and fibreglass in resin matrixes is used to provide them with strong hitting power, durability and stiffness.

Elastomers are used in the manufacture of grips for bicycle handle bars

"Formula 1 race car design too has benefited from advances in chemical technology. The use of polymeric materials in car bodies results in lighter and faster vehicles for car racing, and carbon composite materials help to protect the drivers in the cockpits of open wheel race cars."

Newer sporting products in the pipeline include ones based on nanocrystalline metal/polymer hybrid technology. Such nanometal-polymer hybrids will have metal-like strength and stiffness while allowing for design flexibility and lightweight benefits of high-performance thermoplastics.

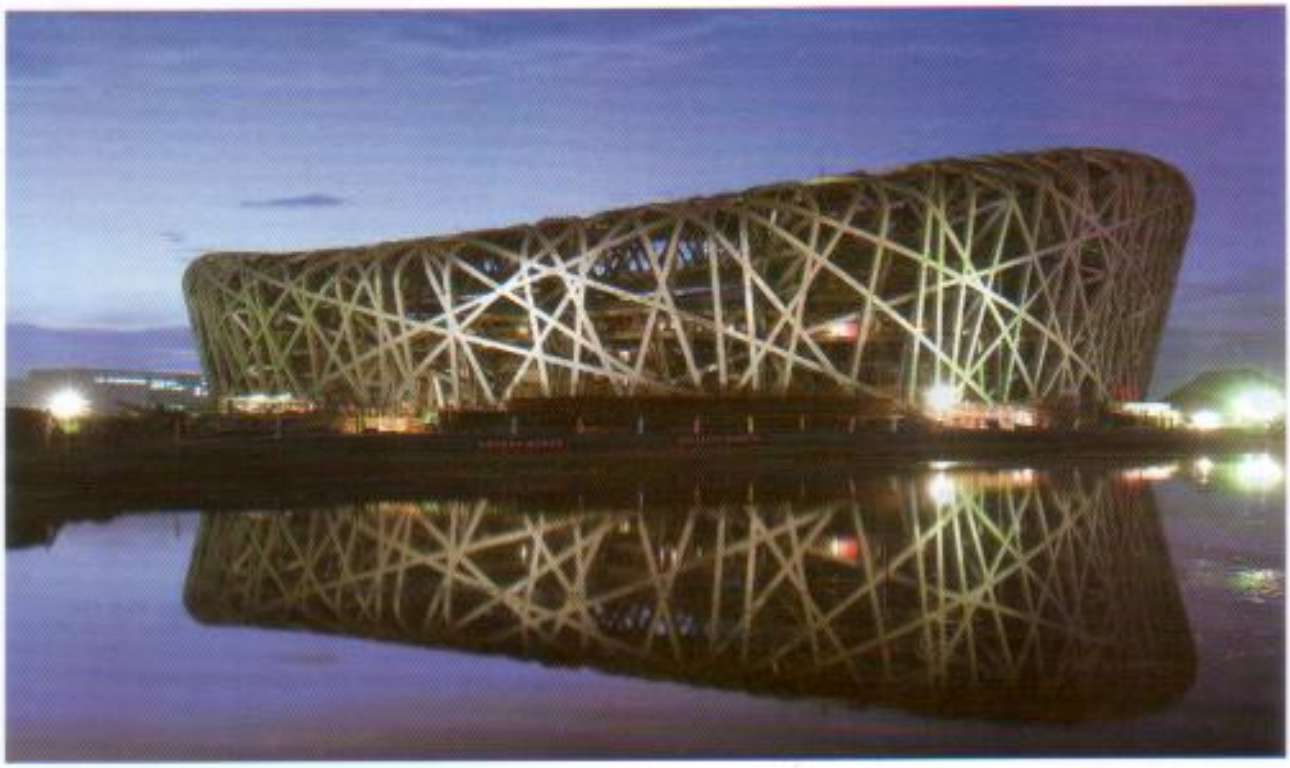
Elastomers are used in a variety of soft touch applications such as straps for a swimmer's goggles, grips for bicycle handlebars and racket handles and foam padding for shin guards. The newest additions to the line of elastomers are olefin block copolymers (OBCs) which have several advantages over the earlier ones such as styrenic block copolymers (SBCs), thermoplastic vulcan-izates (TPVs), thermoplastic polyurethanes (TPUs), ethylene vinyl acetates (EVAs) and flexble polyvinyl chloride (f-PVC). For instance, OBCs offer higher heat resistance and improved compression as compared to EVAs, and can perform better under different temperatures as compared to f-PVC. As for footballs, instead of leather, they now have water-resistant polyurethane outer surfaces, and instead of rubber bladders as in the past, today they are kept inflated using polyurethane bladders which are not only more puncture resistant but also cost much less than the rubber ones.

Gone are the days when sports shoes used to mean the humble white "tennis" shoes. From the high-performance soles and the complex adhesives that ensure the shoe remains intact under extreme conditions, to the "breathing fabrics" that keep the feet cool and dry, advanced technology is involved in the construction of modern day sports shoes. Super lightweight foams first developed by NASA, no less, are being adapted for use as insoles in performance footwear. The soft foam provides superior protection for the fragile foot bones and evenly distributes the body weight over its surface. Besides, "flywire" (a high-performance multifilament yarn spun from liquid crystal polymer) technology makes it possible to exploit the high tensile strength, flexibility and light weight of the fibres to create super-light, durable and comfortable sports shoes. The high-performance strands work like cables in a suspension bridge, providing cushioning as also support, exactly where an athlete's foot needs it.

Formerly made of leather and now out of polycarbonate, safety helmets used in sports like rugby, hockey and bicycling have evolved both in design and the way they are manufactured. The present day polycarbonate helmet was introduced in 2002. In a recent model, the traditional foam or polyurethane pads were replaced with a series of air-filled thermoplastic shock absorbers.

Formula 1 race car design too has benefited from advances in chemical technology. The use of polymeric materials in car bodies results in lighter and faster vehicles for car racing, and carbon composite materials help to protect the drivers in the cockpits of open wheel race cars. In fact, carbon fibre is now used in most areas where previously there were heavier metallic components and is therefore now used for just about everything from brakes and suspension wishbones to bodywork and heat shields. A major problem with race cars is the tremendous amount of heat soak that can be generated. Therefore heat shields made out of a high temperature phenolic carbon, a material originally developed for rocket nozzles, are fitted in racer cars to mitigate the heat produced. To impart maximum strength to the chassis, they

Use of polymeric material in car bodies results in lighter and faster vehicles for car racing.



Bird's Nest Stadium

are made using a sandwich construction with an aluminium honeycomb filling between layers of carbon fibre.

Sportswear

Sportswear, which is often critical to an athlete's performance, also relies on modern materials and chemicals. At the 2008 Beijing Olympics it was not just Michael Phelps and his record breaking eight gold medals that created a splash. There was a big buzz about his new high-performance swimsuit, designed with the help of NASA, as well. The revolutionary swimwear, touted to be the world's fastest swim suit, is the world's first fully bonded suit that is ultrasonically welded and has no seams or material overlaps that could act as speed bumps on the body. The swimsuit features a thin water-repellant polyurethane membrane embedded in the nylon/elastane fabric at strategic parts of the body to reduce drag and improve speed.

Besides helping in enhancing speed, consumers also expect sportswear to be comfortable, lightweight and be able to adjust to the needs of the body over a wide range of external temperatures and activities. Thermoplastic polyurethane is used in cold weather sportswear such as ski boots, skates, ice hockey boots, hiking and climbing boots and also in ski/snowboard surfaces. Sports apparel is generally made from performance fabrics specially engineered for comfort and providing temperature regulation. Such fabrics maintain the body temperature at a level that will maximize performance. That is, they are so designed as to keep the body warmer or cooler, and are geared for one or the other. Nylon, rayon, polyester, polypropylene, wool and polyurethane elastane fibres or blends of different fibres are some of the materials used for making sports apparel.

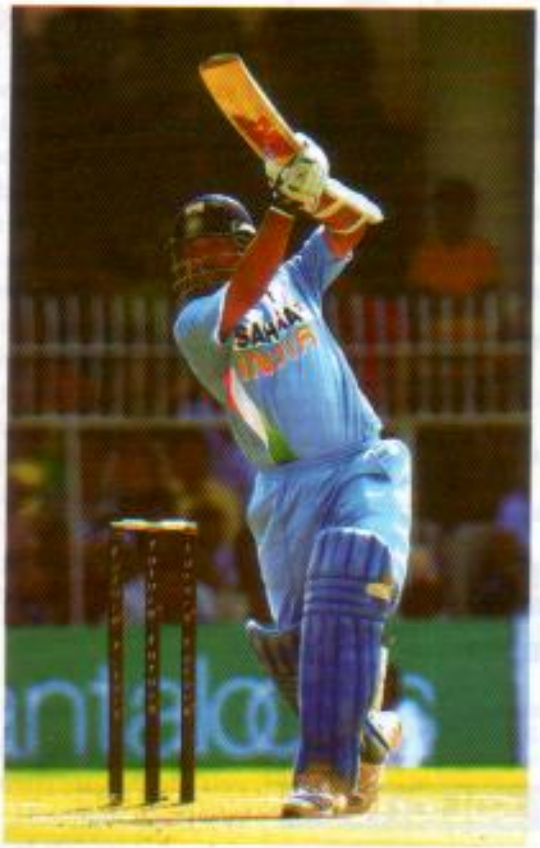
"Super lightweight foams first developed by NASA, no less, are being adapted for use as insoles in performance footwear. The soft foam provides superior protection for the fragile foot bones and evenly distributes the body weight over its surface. Besides, "flywire" (a high-performance multifilament yarn spun from liquid crystal polymer) technology makes it possible to exploit the high tensile strength, flexibility and light weight of the fibres to create super-light, durable and comfortable sports shoes."

Sports Surfaces

Chemicals played a starring role in the recent 2008 Beijing Olympics by way of not only the high-performance sports equipment and apparel used by sportspersons, but also the inventive roofing and flooring of stadiums and specialized surfaces for different sporting events.

The remarkable Bird's Nest stadium which became the symbol of the Beijing Games had a roof consisting of thousands of translucent air-filled pillows made from ethylene tetra-fluoroethylene (ETFE), a lightweight plastic film weighing just 1% of an equivalent-sized glass panel, clinging to a giant steel cage. Another membrane layer made from polytetrafluoroethylene (PTFE) ensured sound insulation inside the stadium. The aquatics centre had a similar roof fitted with inflatable plastic pillows. The innovative roof enhanced the building's energy efficiency by trapping solar energy for heating the swimming pools while at the same time providing natural light and reducing the electricity consumption. Polycarbonates are another preferred material for stadium roofs because they are lightweight, transparent and can be shaped into creative architectural designs. At the Beijing Games, the roof of the football stadium was made out of transparent polycarbonate sheeting shaped like a petal.

Sports tracks and surfaces can enhance the performance of athletes, enabling them to run faster, jump higher or move better. The artificial surfaces in use in sports arenas today are preferred because they are all-weather playing surfaces that are more durable and are easier to maintain. But athletes want much more than that. They want surfaces that have better performance-enhancing and safety features, such as better traction and speed as well as better shock absorption. And so these features were also taken into account while developing such tracks and surfaces.



> "Modern sports tracks can be either fabricated offsite and then glued directly onto the asphalt with a special adhesive, or can be liquid tracks that are put together onsite."

Synthetic sports tracks were first introduced at the Mexico Olympics in 1968 and ever since research on improving artificial tracks is being carried out to help sports- persons perform at their best while at the same time providing them with maximum protection from injuries. The track at the Bird's Nest stadium was made from renewable natural rubber, natural fillers and colour pigments.

Modern sports tracks can be either fabricated offsite and then glued directly onto the asphalt with a special adhesive, or can be liquid tracks that are put together onsite. A sophisticated track of the latter kind is based on a sandwich system comprising an elastic base layer of rubber granules and a polyurethane binder applied in situ to the asphalt substrate with built-in finishers. A pore sealer is applied over this layer, followed by a self-levelling polyurethane coating made of two components which are mixed on site, applied to the appropriate thickness and then spread with coloured rubber

granules while still in the liquid state. This coating then hardens as a result of the reaction of polyols and isocyanates to form a highly elastic polyurethane top layer. In general, most synthetic tracks can last for around 20 years. Resurfacing could extend their life span by another 10 to 20 years.

Many among the crowds that fill modern stadiums to watch football or hockey matches today would be surprised to know that what looks like freshly mowed green grass on the playing field is actually artificial grass. Also called astroturf, such artificial pitches, manufactured from synthetic materials like polypropylene (PP) or polyethylene (PE), are widely used nowadays for different sports. First developed in the 1970s, artificial grass was further modified in the 1980s to include a latex base layer with a sand infill for providing an effective drainage system and making the turf fit for playing under all weather conditions. The base layer also acts as a shock pad.

Some varieties of synthetic turf in use today fall under a more superior "third generation" category which is almost as safe to play on as natural grass. One such turf comprises a top layer of soft artificial grass fibres made from PP/PE over a backing of latex and polyurethane.

Leaping over the anti-environment hurdle

Thanks to green technologies being developed today, the sporting goods and surfaces industry is also showing signs of going green. Artificial turf, ski-boots, goggles, running shoes and many other high-performance sporting goods incorporate renewable-based chemicals, recycled materials, or both. Nowadays, many synthetic grass and track manufacturers use up to 70% recycled materials such as plastic bottles and rubber tyres thus offering more environment friendly products. Bio-polyols sourced from corn or other natural-based feedstock are used for manufacturing ski goggles and watch straps, bio-based polyamides are used for making spectacle frames, soy-based inks, water-based adhesives and bio-based thermoplastic elastomers are used for making running shoes, recycled engineering plastics are used in lacing systems, fishing reels, components of fitness machines and mountain gear, the list is growing longer each year.

As the sporting world keeps evolving and the needs of athletes and different sports keep changing, you can be sure chemists will be hard at work to satisfy these demands, coming up with even more advanced materials in ways we can't even imagine today.

References

1. Guinevere A. Giffin, Steven R. Boone, Renée S. Cole, Scott E. McKay*, Robert Kopitzke, *mckay@cmsu1.cmsu.edu : *Modern Sport and Chemistry: What a Chemically Aware Sports Fanatic Should Know*
2. Sanjay S. Chaudhari, Rupali S. Chitnis and Dr. Rekha Ramkrishnan: *Waterproof Breathable Active Sports Wear Fabrics* - The Synthetic & Art Silk Mills Research Association, Mumbai
3. Rachel Uctas: *Olympic flooring boosts athletes' performance* – ICIS Chemical Business, 30 July 2008
4. Cynthia Challener: *Sports is a key market for carbon fiber* – ICIS Chemical Business, 18 August 2009
5. Doris de Guzman: *Sports gear industry increases use of renewable-based chemicals* – ICIS Chemical Business, 17 August 2009
6. Johann Thim: *Performing plastics- How plastics set out to conquer the world of sports* - Chemistry & Industry, 7 February 2005.

*