The Olympic and Paralympic Games are the most recognised multi-sport events globally, attracting viewers from across the world as the finest athletes face each other for the chance of ultimate sporting glory every four years. The pinnacle of elite sport is always rising, and Olympic and Paralympic athletes put themselves through gruelling training regimes and regimented diets to keep themselves at the forefront of athletic performance.

But these days you could not win gold without having the right chemistry in your equipment and clothing. Innovative new materials and chemistries help drive the performance of the world's best athletes to new heights. These new technologies are present in many facets of the Games. In this article, Natrium Capital explores the important role chemistry plays at the Olympics and Paralympics and how chemistry helps to win gold and break records.

INTRODUCTION

As Olympic and Paralympic fever starts to set in, Natrium Capital has looked at some of the ways modern-day chemistry shapes the world's most famous sporting event, exploring some key examples of chemistry in action to look out for over the course of the next couple of months. Chemistry is everywhere to be seen at the Games if you look for it, from the equipment athletes use, to the courts and tracks they compete on, to the clothes they wear.

THE CHEMISTRY OF SPORTS CLOTHING

The endless search for optimisation in the world of elite sport extends to every possible area of the games, especially the clothes worn by athletes.

Swimming has been the subject of extensive sportswear materials research focused on minimising the drag forces experienced by athletes in the pool to make them as streamlined as possible. A significant turning point occurred at the Beijing Olympics in 2008, where Speedo released new full-body **polyurethane** swimsuits. The foam-like nature of the **polyurethane** trapped packets of gas, making the swimmers more buoyant in the water, with the lightweighting effect aiding high performance. The suits were also water-repellent, pushing water away from the swimmer and hence reducing drag further.

The use of these full-body suits contributed to a record number of swimming world records in 2008. Full-body swimsuits have since been banned: men's swimwear is not permitted to extend past the knee or the navel and women's swimwear cannot cover the neck. Crucially, **polyurethanes** are no longer permitted for use in Olympic swimwear. Swimsuits must now be made from natural or synthetic yarns, and there are stringent restrictions on both the permeability and buoyancy of the suits.

Figure 1. *Swimwear has been heavily regulated following revolutionary technological advancements*

Materials such as elastane have risen in popularity, reflecting a change in focus away from the minimisation of drag towards optimising energy storage and muscle compression.

Further research has also been invested into optimising goggles and swim caps. Olympians typically wear two swim caps – an inner **latex** one, which should stick to the head effectively, and an outer **silicone** one, exploiting silicone's resistance to creasing and water repellence. Moreover, goggles with **polycarbonate** lenses are used due to their shatter resistance and durability, and are shaped into flat lenses to minimise drag.

In athletics, recent records crucially depend on having the right shoes and it has been a contentious area of late indeed. The design of the mid-sole of running shoes has revolutionised in the last few years to enable improved cushioning and elasticity. A complex blend of polymers, including **polyurethane** foams and **silicone**, are commonly used, with novel and even more advanced polymer combinations often found in higher-performing shoes. **Carbon fibre** plates are used between two foam layers in running shoes to allow the foams to compress and expand faster, improving energy efficiency. World Athletics reacted quickly to this exceptional technology and, in 2020, they stated that shoes must not contain more than one **carbon fibre** plate. Swiss company On has developed an innovative new way of producing running shoes which is challenging the likes of Adidas and Nike. Their LightSpray technology uses a foot-shaped mould held by a robotic arm. This is then sprayed with **thermoplastic polyurethane** whilst the arm rotates to ensure the correct thickness is generated. The spray then coalesces to form the shape of the resulting shoe. These "spray-on" shoes will be in use by some long-distance runners at the Games this summer.

Figure 2. *Shoe design in athletics is a core area of focus*

Cycling clothing is designed to make the cyclist as aerodynamic as possible. Track cyclists wear whole body suits made from **elastane** or **nylon** to minimise drag, while road cyclists and mountain bikers wear jerseys and shorts made of similar materials. This helps them to shave precious seconds off their times in their quest for the gold medal.

THE CHEMISTRY OF SPORTS EQUIPMENT

Carbon fibre composites have revolutionised sports equipment because of their unique combination of stiffness and low density: boats used for rowing and canoeing events have long been made from the lightweight material; hockey sticks invariably contain carbon fibre as the principal component; it also plays a crucial role in tennis rackets, golf clubs and bike frames.

Figure 3. *Carbon fibre is used in a wide range of sports including rowing and hockey*

In the Paralympics, running blades for paralympic runners are also made from **carbon fibre**. Alongside **aluminium**, it is also the main material used for paralympic wheelchairs. These materials ensure that the equipment is extremely lightweight for fast and easy movement.

In bicycles, **carbon fibre**'s stiffness ensures efficient energy transfer and it is considered superior because of its reduced weight relative to the traditional options of **aluminium**, **titanium** and **steel**. Cycling teams are always seeking marginal gains and new material solutions have even been proposed for smaller components, such as the bike chains. In 2016, Team GB's cycling team used Muc-off's innovative bike chains, using a **carbon nanotube**-based lubricant which claimed to increase efficiency by a few watts. Of course, at this level, every watt matters!

Figure 4. a) *Olympic bike frames are now based on carbon fibre;* ***b)*** *Golf technology improvements have led to an increase in average driving distance at the top level of over 25 yards since 2000*

Golf was reintroduced as an Olympic sport in 2016 after more than a century-long absence. A range of materials in addition to **carbon fibre** are used for manufacturing golf clubs. Each golfer is allowed to carry a maximum of 14 clubs in their bag, with each club designed for a specific purpose. The driver is designed to maximise distance off the tee. Although ironically called a "wood", most drivers are primarily made out of **titanium alloys** due to the metal's high strength to weight ratio. Common other metals used in the alloy are **aluminium** and **vanadium**. However, other smaller clubs designed to hit the ball directly off the turf do not usually contain **titanium** because the clubhead would feel unusually light. Recent driver designs have substituted the traditional steel shaft for composite shafts comprised of **carbon fibre** with **epoxy**; clubhead speed, the all-important factor in generating distance, is improved by the lower density and weight reduction properties endowed by composites. By far the most common material in golf club manufacturing is **stainless steel**, desirable due to its inexpensive nature and straightforward ability to be cast and shaped into various clubs. **Carbon steel** is used as a softer material for enhanced feel in wedges and putters, where the world's best seek to use finesse and touch around the greens.

Golf ball design has evolved significantly over the years, with the latest models usually made of three parts: the core, the mantle and the cover. The polymer-infused rubber core, typically **polybutadiene**, stores and subsequently releases the energy from the impact of the club. The mantle layer is now commonly comprised of **ionomer** or **thermoplastic resin** which substituted the historical use of rubber bands wound around the core. This helps to reduce the spin generated from the core and increase ball control. The cover, typically made of **urethane** or **ionomer resin**, must be stiff to maximise energy efficiency, but not so stiff as to crack.

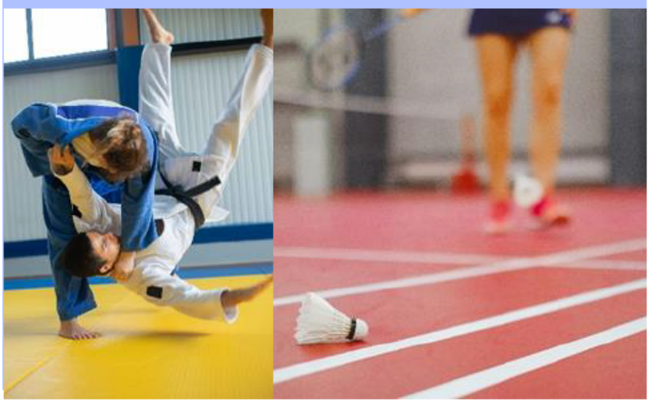
Tennis rackets also use a range of materials. The primary material for the frame is **graphene** blended with other materials such as **titanium**, **tungsten**, **carbon fibre** and even **Kevlar**, the high-strength synthetic fibre used in bulletproof vests. The racket strings are either made from **natural gut** from cow intestine, **polyester**, or **nylon**, or some combination of these materials.

Figure 5. *Tennis rackets contain a range of materials*

THE CHEMISTRY OF THE ARENA

The playing surfaces themselves hold some very interesting and varied chemistry. Many surfaces look like they are made from some kind of plastic, but as we shall see, there is no such thing as just "plastic". For example, the indoor synthetic badminton courts are layered with polymers such as **PVC** or **polyurethane**. These are considered advantageous for their effective shock-absorbing qualities, good grip, and thin nature which ensures a responsive surface for players to push off from. **Polyurethane** is a popular material in sports surfaces and is a key component in binding synthetic rubber particles in athletics tracks. **Polyurethane** is also sometimes used in the foam blocks incorporated into the plywood gymnastics floors to ensure a springy but shock-absorbing nature, although the usual polymer used for this purpose is closed-cell **polyethylene** foam. Meanwhile the mats used for martial arts events, such as taekwondo and judo, are made of closed-cell **PVA** foam.

Figure 6. *Sports surfaces are often made from*



Taking a dive into the water-based arenas, Olympic swimming pools are monitored closely and treated with **chlorine** to kill any harmful bacteria, as well as with **soda ash** and **sodium bisulphate** to control the pH levels to maintain a safe environment for the athletes. Pool water treatment famously went significantly wrong at the Rio Olympics in 2016 when a large dump of hydrogen peroxide, a dechlorinating agent, into the diving pool turned the poolwater bright green. Diving boards are made from aircraft-grade **aluminium alloy** coated in a slip-resistant material.

In the world of open water swimming, a lot of recent comments have revolved about the extensive cleaning of the Seine in preparation for the Olympics. This has included new water-treatment initiatives to prevent stormwater from entering the river and plastic waste disposal projects. The aim is to make the river, which has been deemed unsafe for swimming in the last century, suitable for the outdoor swimming events this summer. Natrium Capital staff hope to test this for themselves when swimming in the Seine is opened to the public!

Figure 7. *Swimming in the Seine has been forbidden for the last*

CONCLUSION

Floods of research have been poured into advancing technologies for elite-performance sport and there is no doubt that this will continue to be the case in years to come. The face of sport looks very different from half a century ago in many ways; gone are the days of heavy metal bike frames, golf balls wound in rubber bands and the leather running shoes from "Chariots of Fire".

Elite sport is now dominated by lightweight, responsive materials which maximise the athletes' speed, strength and power.

Without taking away from the athletes' amazing achievements, no record would be broken these days without the correct clothing or equipment, which has been developed and produced using advanced chemistries. So when you are glued to the television screen this summer in awe of the athlete's performances, or if you are lucky enough to be at the Games in Paris, remember to spare a thought for the numerous chemists worldwide who push the boundaries of what is possible at the Olympics.

ABOUT NATRIUM CAPITAL

Natrium Capital Limited is the specialist Chemicals M&A boutique which sets a new standard in M&A advice. Led by Alasdair Nisbet and staffed by bankers, all of whom are also scientists, Natrium Capital provides strategic and M&A transaction services focused on the chemical industry, covering, amongst others, the sectors: plastics, fine and speciality chemicals, personal care ingredients, food ingredients, chemical distribution, engineering materials, paints and coatings, inks, adhesives, biotechnology and clean technologies. Headquartered in London (UK), Natrium Capital advises on both sell-side and buy-side transactions, including carve-outs and complex global cross-border deals. The team has advised on transactions with a combined value of over $100bn.

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