IMOA
INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

What makes a watch tick? Moly!

Mechanical watches rely on a tightly coiled strip known as a mainspring for power. Without the mainspring, these watches and other timekeeping devices like metronomes could not exist. The humble mainspring is exposed to great forces within the watch, necessitating uniquely hard materials with superior fatigue resistance. Today, most mainsprings are made of a specialty molybdenum-containing alloy.

Mechanical watches tell time without batteries, circuitry or an external power source. Instead, winding a watch loads its mainspring with power that sets the gear train in motion. The mainspring is the backbone of the watch. It stores energy that is released in precisely timed intervals by what's known as an escapement. The escapement mechanism prevents the mainspring from unloading all its power at once and spinning the hands of the watch like a jet turbine. Instead, the regulated energy off the escapement wheel moves the gears of the watch in increments that accurately measure the passage of time. Automatic mechanical watches work similarly, except the winding is replaced by a weight that passively generates power as the wearer moves their arm. In many watches, each part is a painstakingly crafted work of art, which approaches perfection in its mechanical accuracy. Even the seemingly simple mainspring is a metallurgical marvel, centuries in the making. Molybdenum-containing alloys play an indispensable role in the mechanical properties of nearly all watch mainsprings and certain other watch parts.

The balance spring (left) is connected by a train of several gears to the mainspring (right), regulating the release of mainspring energy to constant, second-long intervals.

The history of timekeeping

Various tools have recorded time throughout history. Sundials, water clocks and candle clocks ranging from simple to unimaginably complex kept humanity on track for millennia. Contemporary mechanical clocks and watches first appeared in Europe approximately 600 years ago. The invention of the mainspring was indispensable to modern clock and watchmaking. Before the mainspring, clocks were powered by weights. A weighted rope coiled around a pulley used gravity to power the clock. Even this design did not occur until the 12th century AD, possibly later. The mainspring enabled smaller, portable designs for the first time in history. Who invented the mainspring, however, remains a mystery. The oldest spring powered clock known dates to 1430. It is a lavish gold piece made for Phillip the Good, the Duke of Burgundy, and is housed in Germany today. Though the origin of the modern mechanical watch remains unknown, by the 16th century, portable "clock watches", sort of like an early pocket watch, were popular in central Europe. However, these early devices were so inaccurate that they were used mainly as gear-powered jewelry for curious nobles.

In 1657, watchmaking took a giant leap with the invention of the balance spring, also known as a hairspring. The balance spring is part of the escapement mechanism, a particularly complex and elegant part of a watch's movement. This invention reduced watches' margin of error from several hours a day to approximately 10 minutes. Today, world-class watchmakers note that the difference of a micrometer in the width of the balance spring can make the watch off by 30 minutes.

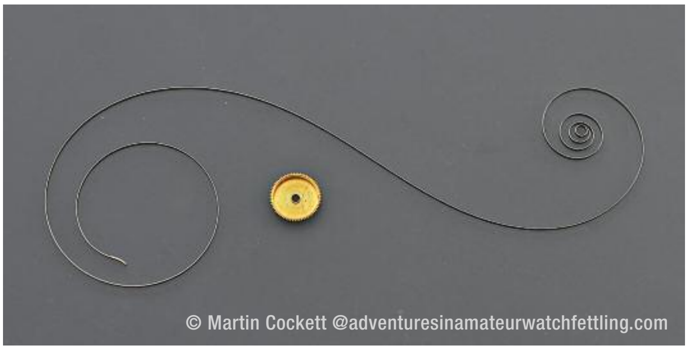
Even in the 18th century, the metallurgy of watchmaking was already a complicated affair. Watchmaker William Blakey wrote many thick books on handcrafting mainsprings. A quality mainspring in the 1780s could take days of highly skilled effort. Making watches by hand was time consuming and expensive, and therefore, it was mainly the rich who could enjoy timepieces.

As with many items now central to life in developed countries, the mass production of watches was made possible only through the mass production of steel. The industrial revolution was the first time in history that huge batches of iron could be produced with consistent properties. Pocket watches or pendant watches for women remained the dominant designs until World War I, which highlighted the utility of lightweight timekeeping devices. From then on, the wristwatch became the predominant design, and the rest is history.

Though watchmaking saw all kinds of wonderful developments throughout the centuries, mainsprings remained problematic. The carbon steel originally used for mainsprings lost significant elasticity and strength over time. As a result, the mainspring often failed far earlier than other parts of the watch. Mainspring repair was the number one reason for watch maintenance until the 1960s, when molybdenum-containing alloys and their special properties became a widespread alternative to carbon steel.

Saving time with moly

Several alloys have been specifically developed in recent decades to produce watches that run for greater stretches in



Mainspring in the barrel (left) and unleashed for cleaning (right). As mainsprings are wound with such force, they must be removed by a special tool to not injure the watchmaker!

between winding. How long a watch runs depends on its power reserve, or the amount of available mechanical energy stored in the mainspring. With these alloys, the most popular of which contain molybdenum, watches have longer and longer power reserves. The material for the mainspring must be very strong, elastic and tough. It also needs superior fatigue resistance to withstand years of cyclic loading. If the mainspring fails, it's not a simple replacement: a broken mainspring can damage or destroy the entire gear train of the watch, which is why today they are safely encapsulated in a barrel. Molybdenum-containing alloys offer a greater elastic limit and are less subject to breakage and permanent deformation than traditional carbon steel, making these springs last much longer. Because of its intricacy, mainspring manufacture remains a highly specialized craft – watchmakers almost always order them from one of the world's few producers.

Mainspring materials contain as many as 10 alloying elements, all of which affect the final properties of the spring. Molybdenum specifically helps with hardenability and strength, as well as ductility which are necessary for highly loaded tiny parts. It also improves the corrosion resistance of these alloys. The most popular mainspring alloy is NIVAFLEX®, a cobalt-nickel-chromium alloy with 4% molybdenum. Its very high tensile strength of 3000 MPa gives it incredible fatigue resistance. SPRON 510, with up to 10% molybdenum, and Bioflex®, with 2.5 to 4% molybdenum, are other popular choices for mainsprings.

The influence of magnetic fields can also negatively and substantially impact the accuracy of a watch. It is therefore important that watch parts are non-magnetic. Molybdenum alloying helps to make Nivaflex non-magnetic at temperatures typically encountered by a wristwatch. For this reason, sometimes other precision watch pieces like winding stems also necessitate molybdenum-containing alloys.

Balance springs, too, were traditionally made with carbon steel and suffered from similar problems as mainsprings. Like the mainspring, balance springs must be exceptionally hard and fatigue resistant, yet also be ductile and able to be machined to extremely minute tolerances. The best-known balance spring material is NIVAROX® CT, which contains as many as seven different alloying elements, all of which are decisive for setting the material properties, mainly a low temperature coefficient of elasticity. That in particular enables the timekeeping element, the watch's balance wheel, to keep better time. Although Nivarox does not contain molybdenum, at least one recent patent application exists for a molybdenum-containing balance spring that leverages the element's unique properties. Molybdenum even comes to the aid of watches in chemical form: several mechanical watch brands use molybdenum disulfide lubricants on gears and in the mainspring barrel to keep the timepiece running smoothly.

Mechanical watches embody centuries of ingenuity, artisanship and curiosity. Though many feared that these works of art would disappear in the wake of battery-powered quartz watches – and now smartphones – the mechanical watch industry remains vibrant. Take for instance the flamboyant watch enthusiast community on YouTube; evidence that the elaborate movements continue to enrapture successive generations of watch fans worldwide. Their tick and movement calls attention to the passage of time in a way the smartphone cannot. Above all, mechanical watches harken back to an era where time actually seemed to run slower. Molybdenum in their most essential components helps keep the nostalgia, tradition and pursuit of mechanical perfection alive in a digitized age. (Karlee Williston)

Many thanks to Alberto Bracchi, Vacuumschmelze GmbH and Alberto Sicco, Générale Ressorts for their valuable input.