Micro-machining technology: a primer

John Beigel

Micro-machining technology, simply stated, is the utilization of semiconductor manufacturing equipment in such a way that it creates micro-mechanical systems that serve a specific purpose. MEDER's objective was to develop a micro-miniature hermetically sealed reed switch that is able to function exactly like the larger, standard hermetically sealed reed switch.

The basic critical requirements for reed switches are that the contacts must close when they come in proximity of a magnetic field of sufficient strength, and they must draw zero power when in the off/open state. MEDER has developed a micro-miniature hermetically sealed reed switch in partnership with the Swatch Group of Switzerland, and outside of the Swatch Group, MEDER is the worldwide exclusive marketing arm for the micro-machined miniature reed switch.

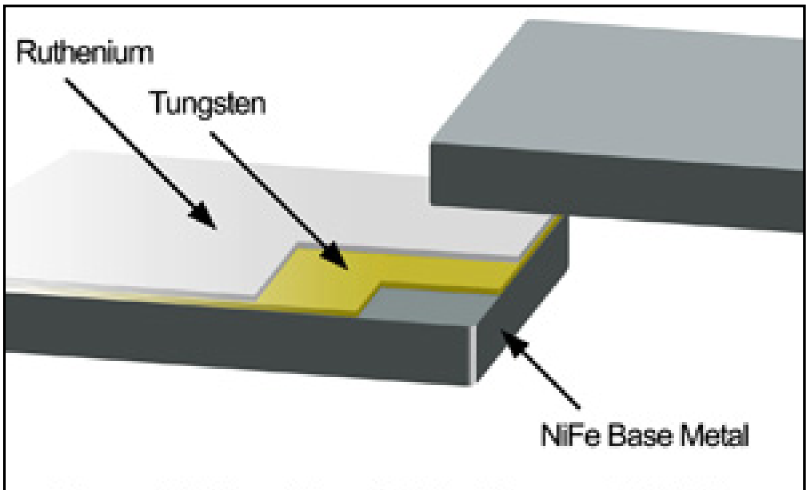

Figure 1. A reed switch is shown within its under plating

By definition, a reed switch is a small electromechanical device having one or more ferromagnetic reeds hermetically sealed in a glass envelope. When the reed switch is brought into a magnetic field, the reed(s) will close, creating a switching function. (A typical reed switch is shown in Figure 1). The nickel/iron base metals are relatively soft materials, and would not be good choices for use in a reed switch. This is because high switching loads initiate massive metal transfer, which could soon cause the contacts to become stuck in the closed position. However, its ferromagnetic properties are essential for proper magnetic actuation. A more preferable manufacturing option is the use of a hard metal at the switching contact surface.

Typically, rhodium and/or ruthenium have been used, which offer dramatically longer life to the reed switch. However, whether one is plating or sputtering the hard metal layer to the ferromagnetic leads, a transition layer is needed to insure that all the metals metallurgically bond to each other. Often gold, copper and tungsten are used as transition layers.

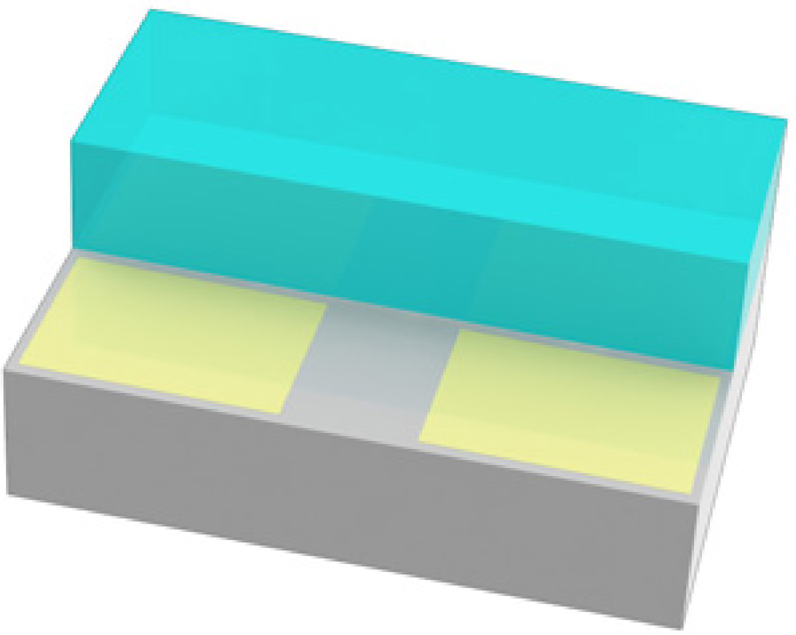

Figure 2. A hermetically sealed micro-miniature reed switch

With our new micro-miniature hermetically sealed reed switch (shown in Figure 2) borosilicate glass is used, with a thickness of 0.350 mm at its lower section, and 0.40 mm at its thick upper section. A proprietary metalization process is used on the edges of the glass so that it becomes hermetically sealed when bathed in a temperature of approximately 320°C. The blade material is rhodium, with a thickness of 0.15 microns, on a nickel/iron base. The contact gap is 4 to 5 microns with argon gas as the cavity medium. To accomplish this, two 4 inch wafers are used, each of which houses over 10,000 devices. The top and bottom are then mated together, and the entire wafer then undergoes the hermetic sealing process.

Over the years, the micro-miniature reed switch has continued to improve, using a continuous improvement philosophy. For example, initially, many laboratories, college research facilities, and semiconductor foundries thought that an epoxy seal would be sufficient. This turned out to not be the case. Epoxies have the tendency to continually out-gas at very small levels, and this is exacerbated by increased temperatures. Any small film (epoxy-related) on or in the contact area proved to be fatal to the reed switch. This is because these epoxy-related films created an amount of insulation that was sufficient to prevent any voltage, current or signal transfer through the contacts. This did not occur all of the time, but enough of the time to reduce long term reliability of reed switches, and thus this manufacturing approach was disqualified.

After some qualification trials and different masking approaches, a truly hermetic micro-miniature reed switch with a glass to metal seal was finally achieved. The reliability of this switch has been demonstrated repeatedly on large populations, with lifetimes exceeding 100 million operations. We have also found that this reed switch is essentially impervious to shock, as it has been tested up to 5000 G's with no faults detected. This is in contrast to the bigger reed switches which are manufactured in the conventional manner and can only withstand shocks of up to 100 G's. Another critical qualification test was long term exposure to high temperatures – with the contacts in the open and then the closed state. We chose 100°C as our bath temperature and soaked the switches for several weeks in each state. Over 1,000 switches were tested in this environment and there were zero failures. The reed switches produced for commercial applications undergo a 16-hour quality control screening where they are temperature cycled and temperature screened from -40°C to 125°C with a dwell time of one hour at each temperature.

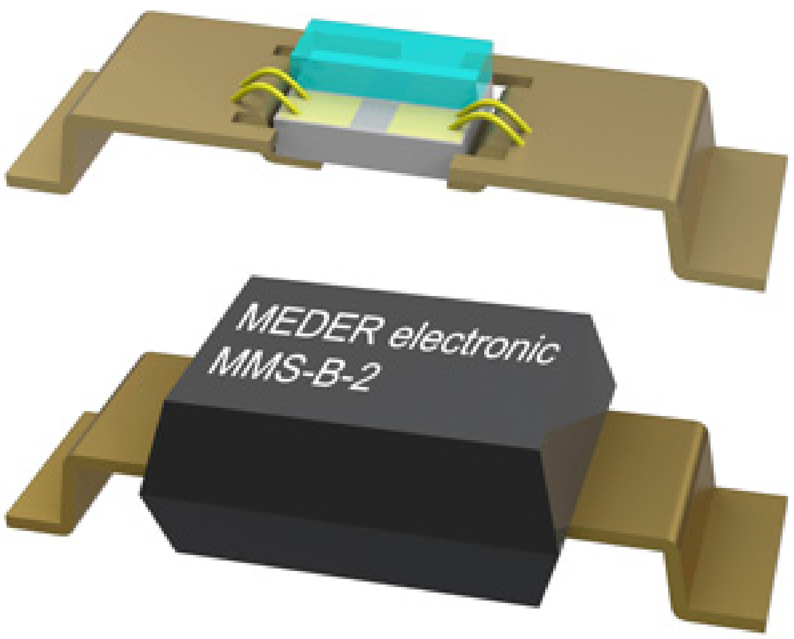

Figure 3. Micro-miniature reed switch over-molded on a gold plated lead frame

After significantly improving the micro-machined reed switch, we then developed different packages which make it easier for customers to mount the switch on the printed circuit boards for their given application. We have added a ferromagnetic lead frame in one packaging scheme, which dramatically adds to its magnetic sensitivity (see Figure 3). This allows the customer to sense and activate from greater distances.

The use of stringent qualification testing has allowed us to design the micro-miniature reed switch into applications requiring high reliability. For example, it has been designed into medical applications where proper operation of the switch can often be a matter of life and death. The reed switch is also able to operate successfully up to 200°C, which could be very useful in certain applications such as automotives and small home appliances where high temperatures may be involved.

Applications
MEDER’s micro-miniature reed switch has allowed designers to develop new products which were not previously possible. The patented reed switch is the smallest ever invented and has passed the test of time, where it has survived and been successfully manufactured for the last 15 years. Many competitors have tried and failed over the past 25 years.

The following are some examples of the medical applications we have worked on and are designed in:

In-the-Canal Hearing aids
Hearing aids in the past were worn on the outside of the ear, and they hooked over the top of the ear and rested behind the ear. Many people felt self conscious when wearing these hearing aids in a public environment, and some would not wear them at all due to self-consciousness. These large, behind-the-ear hearing aids used a rotary mechanical thumb switch to regulate the volume of sound. Designers have been working on developing a smaller, better hearing aid that would fit in the ear canal. These new high-tech, miniaturized hearing aids have been made possible by the fact that less sound amplification is necessary due to their position closer to the ear drum, in conjunction with the development of integrated circuit technology. In the design of these smaller hearing aids, it is crucial to have a way to adjust the volume and program the microelectronics.

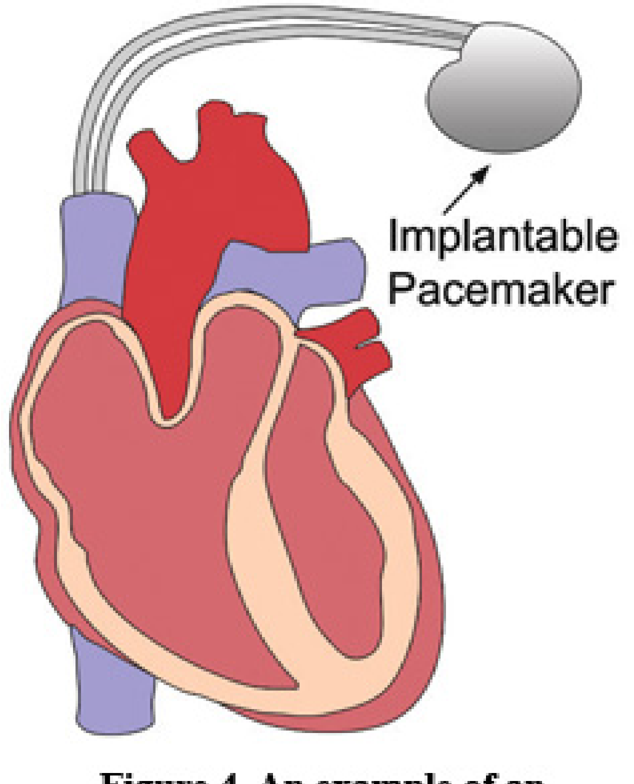

Figure 4. An example of an implantable pacemaker

MEDER’s micro-miniature hermetically sealed reed switch offered the perfect solution. A small wand (similar to, but smaller than, a pencil) with a magnet mounted on its end activates the reed switch, when brought in proximity to the ear. This initiates the setting of the various modes and volume controls so vitally needed. This remote activation, offered by the reed switch, was the essential ingredient for the solution to smaller, in-the-canal hearing aids.

Pacemakers and Implantable Defibrillators

With the invention and use of integrated circuits over 40 years ago, the first pacemakers were introduced. These first ones were very, very large by today's standards and could not be implanted in the human body. Over the years, they have undergone dramatic size reduction with the increased miniaturization of all components, making it possible to implant the pacemaker in the human body (see Figure 4). Reed switches played a big role in the implantation as they allow communication with the device after it is implanted in the human body. When an external magnet is placed near the chest cavity, it causes the reed switch contacts to close, allowing communication with the implanted device. After the micro-miniature reed switch closes, information in the pacemaker can be wirelessly downloaded, heart rate can be adjusted, calibration can be initiated, and/or different modes can be set. The battery life in these implantable pacemakers is lengthened by the fact that when the reed switch is in the open position, only a minimal amount of battery power is used. When the reed switch is closed/activated (for programming, etc.) battery draw is increased only momentarily. Thus, battery power is greatly conserved. Using the micro-miniature reed switch, the pacemakers have become only the size of a thick 'silver dollar'. Now the pacemaker and defibrillator are together in one unit and still not much bigger than the 'silver dollar' design.

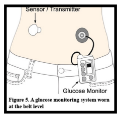

Figure 5. A glucose monitoring system worn at the belt level

Micro-Glucose Detection and Administration Systems

As anyone diagnosed with Diabetes Mellitus will tell you, pricking yourself and sticking yourself with a needle up to 8 times a day is far from optimal. The traditional method for Diabetes treatment is to check your blood sugar 4 times a day, and then administer a specified dose of insulin based on the blood sugar level detected. Each insulin shot administered helps to control blood sugar but it also causes a shock to the system and can cause a cumulative, negative effect on the organs of the body. Doctors and medical electronic designers have teamed up to develop a better, unified system for insulin administration which mimics the natural function of the pancreas. Specifically, a sensor implanted in the waist area is used in conjunction with a small insulin reservoir and dispense system which is worn externally on the waist (see Figure 5). A micro-miniature reed sensor is a component of the implant and is used for calibration and mode changes in a manner similar to the pacemaker. With this system, when very small changes in the blood sugar level occur, a small amount of insulin is administered, which corrects the sugar level. This minimizes the "shock to the system", allowing people with Diabetes to live longer, healthier lives.

Pills that are ingested for video filming of internal organs

A few years back, The FDA approved a pill for ingestion which, encased in it, contains a video camera attached to its microcircuit (see Figure 6). This battery-operated device videos its descent into the stomach and through the small intestine as it is swallowed. The tiny camera videos areas of the small intestine unreachable by endoscopy or colonoscopy. This video is transmitted wirelessly for viewing external to the body. The micro-miniature reed switch plays a key role in this pill. These pills, after manufacturing, may sit in inventory and later in a hospital stocking area for many months. The pill's battery life is only a few hours. The designers have developed a solution to this by using the micro-miniature reed switch

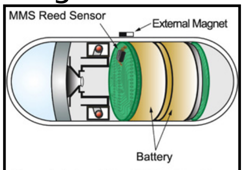

Figure 6. An ingestible pill that videos the entry into the stomach and the small intestine as it moves through the digestive tract

in conjunction with a magnet. In the shipping container, each slot has a magnet dedicated to each pill, and the battery is not yet activated. Once the pill is removed from the proximity of the magnet, the micro-miniature reed switch opens and activates the battery, in turn applying power to the circuitry and video system. Because of these pills, many previously un-diagnosable digestive tract issues have been able to be discovered and treated.

Carotid artery plaque detection, implantable muscle stimulation, incontinence prevention systems, etc.
The number of tiny implantable electronic systems that are being designed and placed in the human body is growing at a rapid rate. These devices have the following in common: they serve to detect a fault in the human body, they need to perform a function when the fault is detected, they often remain in the human body for several years, they are all battery operated, they all use minimal battery power, and they all need occasional adjustments and/or mode changes. The micro-machined hermetically sealed reed switch is used to perform the adjustment/mode changes. Importantly, the reed switch draws no power when in its off state, and after only a brief period of being energized is able to carry out its intended function (e.g. wireless transfer of information, adjustments and/or mode changes).

The micro-machined hermetically sealed reed switch is being used more and more frequently, anywhere the need for sensing does not require physical contact, but rather requires remote sensing on a micro-miniature basis.

Summary and Future Direction
Research facilities, colleges, universities, and businesses have devoted a lot of time and energy using semiconductor manufacturing techniques to develop micro-miniature mechanical systems that can carry out a specific function. The vast majority have found disappointment and failure. MEDER is one of the few that has had success with the development of a micro-machined, hermetically-sealed reed switch, simply because of the long time, effort, and dedication that went into the undertaking. In addition, we have been able to expand our manufacturing by using a more mechanized/automated approach resulting in a higher volume output at lower costs. We are now working on developing an even smaller micro-miniature reed switch, which will initiate new requirements and therefore stimulate new applications.

Author Biography
About the author: John Beigel
Received his BS and MS in Physics from UMass.

Worked for EI&S as Engineering Manager from 1972 to 1981; Coto Technology as VP of Marketing and Engineering from 1981 to 1995; Clare Corp as VP of Marketing and Engineering Relay Division from 1995 to 1998; and MEDER electronic Inc. as CEO for North America from 1999 to 2009 before retiring. Currently consulting for MEDER electronic. In all of the above companies he worked to further the development of reed switch technology.

Source URL (retrieved on *09/30/2014 - 7:06am*):
http://www.ecnmag.com/articles/2011/10/micro-machining-technology-primer?qt-video_of_the_day=0&qt-most_popular=0