Getters — Molecular Scavengers for Packaging

Getters will play a key role in MEMS and MOEMS to enable lower-cost packaging. Dual-purpose moisture-particle getters appear ideal and are already used in some optical MEMS commercial products.

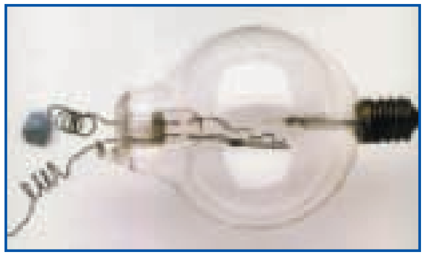

FIGURE 1: De Forest vacuum tube.

By Dr. Ken Gilleo and Steve Corbett

It is the beginning of a new century and a very exciting time for inventors and technologists. The Communications Age is in full swing. Soon, we may be able to talk to anyone from anywhere. The telephone is nothing short of amazing. However, wireless communication is truly miraculous. But many improvements must still be made to realize the real potential.

One key enabling technology is electronic amplification and that is where many have focused their efforts. And finally, there is a breakthrough. Lee De Forest has demonstrated the Audion, a triode vacuum tube amplifier. The year is 1907. Figure 1 shows the De Forest vacuum tube.

While diode rectifier tubes, with a filament and plate had been introduced earlier, De Forest's invention added the all-important control grid to produce amplification. Now, weak wireless signals could be amplified and radio was on the way to becoming a genuine technology. The component "package," a glass envelope, was "pumped down" to remove some of the air. Some gas was allowed to remain since it was thought to be necessary for the device to function. A few years later, others found that performance improved by increasing that vacuum. Progress was rapidly being made, but many problems remained.

The electronic tube's lifetime was typically very short as glowing filaments burned out. The filament, the source of electrons, was run at a high temperature using electrical resistance heating. Oxidation of the wire filament caused overheating and premature burn out. Leakage of air into the glass envelope, of course, would add more oxygen (O_2) that greatly accelerated filament degradation. One solution was to add oxygen absorbers such as active metals. These getters reacted with O_2 more quickly than the filament, which was typically made of high-melting-point tungsten.

21st Century Telecom

A century later, wireless still plays an important role in our communications schemes. But terrestrial and intercontinental links are using an ever-increasing amount of optical fiber for higher bandwidth and more cost-effective communications. Photonics is now the most important long-distance terrestrial mode for the Internet and phone. Photons are harnessed as the favored frugal and fleet messengers of the Telecom Revolution.[1] Although the main core of the Internet still uses electronic routing, this appears to be changing to all-photonics where "light" is routed directly without converting to electronic signals as an intermediate step. The photonic switch will use newly emerging *advanced* MEMS (microelectromechanical systems). When optics is added to this technology, it can be called optical MEMS or MOEMS, for micro-optoelectromechanical systems. This is quite a mouthful, but then again MOEMS is quite a bundle of technology domains.[2,3]

MOEMS Switches

Several optical switch concepts have been implemented recently, but most rely on an array of microscopic movable mirrors that can act as single-axis "on-off" switches or two-axis "point anywhere" light beam redirectors. While there are many designs, the system with the most published data is the DMD™ (Digital Micromirror Device™) from Texas Instruments. TI's micromirror modules now represent the most complex machines in the world in terms of most components and most moving parts. The highest density units contain millions of moving parts, all crafted by semiconductor processing methods that are highly modified. The ability to mass produce such tiny and complex machines certainly represents a new milestone in technology. Figure 2 shows a close up of the movable mirror construction.[4] Figure 3 shows other micromirror concepts from industry and academia.

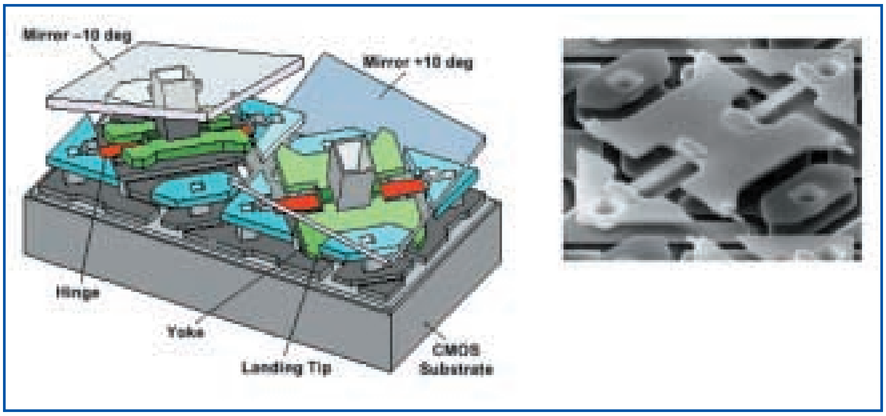

FIGURE 2: DMD™ close up.[4]

The Package

MOEMS packages all have one common requirement — they must have a transparent port or window. Light must be able to enter and exit with minimum attenuation. Let's look at the TI product since information is readily available. The DMD™ product was initially used for digital projectors that are now commonplace at conferences and business meetings. Light from a strong source can be reflected toward the lens (pixel "on") or away (pixel "off") by each of the tens of thousands of mirrors. Figure 4 shows the switching principal. The mirror must be able to respond to an electrical impulse almost instantaneously. This is feasible because of the very low mass of the microscopic structures. However, nearly any kind of contamination is bad news for both the mechanical movement and the delicate optics. The package must exclude micro-particles and gases, especially moisture. This has led to the nearly exclusive use of hermetic packaging, although lower cost quasi-hermetic, or near hermetic types, are under study and appear viable. The DMD system can be redesigned into an optical switch where each mirror controls an input/output (I/O) function.

The high hermetic package may not be enough however. First, it is difficult to remove every trace of gases and particles. But such contaminants can be released or generated from within the package. Outgassing from a number of sources can release moisture. Wear can generate microscopic solids that jam the motion mechanisms. We need a sure means of removing gases and particulate without opening up the package. The simplest solution is getters. TI and others employ modern getters to insure maximum performance and longevity. Let's look now at the types of getters used for MOEMS products.

What are Getters?

Getters are selective scavengers, or attractors, designed to capture and "kill" the undesirable substances. They are the "antibiotics" of the packaging world that seek and "get" the evil contaminants. The list includes getters for several gases, liquids and solids. Important gas getters include oxygen and hydrogen, both found inside of the hermetic package and known to be harmful. The most important liquid getter targets water although as a vapor under the high vacuum conditions. Some of the moisture getters also trap ammonia, sulfur dioxide and other harmful species that can be found in packages. Getters for solids are general purpose and capture small particles regardless of the composition. While other getters can be designed, these are the important types for both high-reliability electronics and MEMS. Figure 5 represents a TI DMD package with getters that has been redrawn for clarity. Moisture and particle getters are especially important for MOEMS devices and can be combined into a single, multipurpose material.

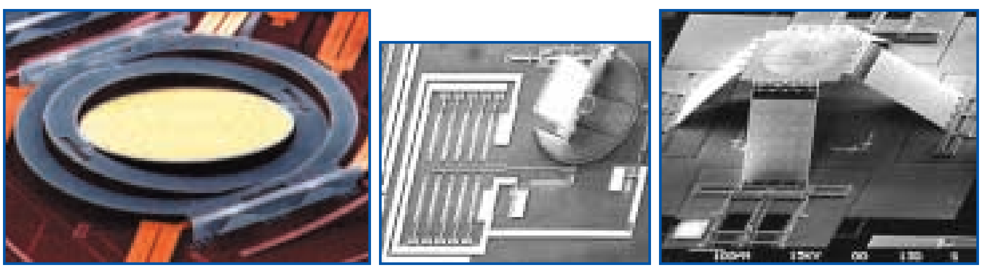

FIGURE 3: Other MOEMS optical switches: left, WaveStar/Lamda router (Lucent); center, rotating mirror (UCLA); right, pop-up lens (UCLA).

Why Do We Need Getters and How Do They Work?

Moisture

Traditional hermetic packages used in military, space, medical and other applications often require high reliability and have an upper limit of 5,000 ppm of water vapor content at the time of fabrication. Package leak rate is limited to 10^{-8} atm-cc/sec maximum to prevent entry of significant moisture during the device's expected lifetime. But it is difficult to manufacture a hermetic packaging for microelectronic devices with low water vapor content and to maintain it during its lifetime of many years. There are mechanisms for water vapor to enter the package interior that include seal leakage, water generated during the sealing process and moisture outgassing from adhesives or even the package. The best long-term reliability assurance requires the use of getters.

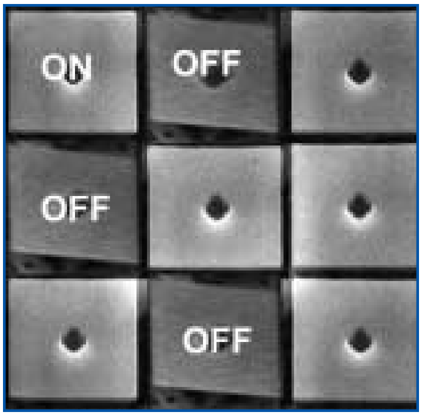

FIGURE 4: DMD™ switch concept.[4]

Moisture getters contain potent desiccants dispersed within a permeable matrix that is typically a polymer. Desiccants can be common inorganic compounds that form hydrates by combining with one or more molecules of water. The chemical attraction for water molecules is the "pump" that dries out the package chamber. Zeolites, and other mineral-type compounds are used in many of the moisture getters. The solid desiccant is finely dispersed and suspended within a plastic film that can be attached to the inside of the package. While film is more common, getters can also be supplied as solvent-born pastes that can be dispensed into the package or onto the lid followed by thermal hardening. Getters can require activation by heating since the desiccant can pick up moisture during storage and application. Heat activation before sealing the package can be used to dehydrate the compound back to a full capacity dry state. Also note that some ceramic packages can absorb water so that the package is the getter.

While moisture is generally bad for any electronic device, it can be especially troublesome for all MEMS products. Moisture will induce a surface contact phenomenon known as stiction. Stiction is a high inter-surface attraction between two parts making contact that causes them to stick together, often permanently. A very high force is required to get things apart or start components moving. It can require a very high initial force to start a mechanism moving if stiction cannot be overcome and will mean excessively large motors. Even tiny mechanical stops for mirrors are subject to stiction. Stiction occurs in the macro-world but goes unnoticed because the forces are small. However, extremely low mass and relatively high surface area of MEMS devices make it a major problem in the nano-world.

But what does this have to do with moisture? Water molecules on a surface can act like a "glue" to greatly increase stiction. And once stuck, a mirror may remain "dead". Relative humidity values of 20 percent or less are said to reduce stiction.[5] Also, H_2O is generally bad for optics since it can fog lenses, corrode mirrors and condense on windows.

A commercial moisture getter, like STAYDRY™ SD1000, from Cookson Semiconductor Packaging Materials (CSPM), is designed for applications up to 400°C. These products ingest water vapor and other corrosive gases such as ammonia, sulfur dioxide and hydrogen sulfide. When fully cured, the moisture absorbing capacity is more than 300,000 ppm/sq.in./mil of coating in a 1-in. × 1-in. package of 1.5 cm^3 free internal volume at 150°C. The capacity increases by 5X at room temperature.

Hydrogen

The idea of a hydrogen getter may seem perplexing. Where would this gas come from and what harm could it do? Electroplated metal packages can release hydrogen that is adsorbed during the plating process. The sealing operation can also produce hydrogen sources. Some of the radio frequency (RF) absorbers used in packages, and even as die attach adhesives, can be H_2 sources. Hydrogen, while not harmful to most silicon devices, can be a slow death to high-speed gallium arsenide (GaAs) devices. A chemical reaction can occur if any platinum (Pt) or palladium (Pd) is present that converts the molecular hydrogen to highly active atomic hydrogen. The hydrogen atom poisons the semiconductors, reducing performance over time. Since many GaAs devices use Pt or Pd conductor layers, hydrogen getters can be critical here. They are typically made with hydrogen absorbing platinum or palladium metals or oxides like PdO. The PdO type, like STAYDRY™ H2-3000 (CSPM), is highly effective since hydrogen is converted to water that is then removed by a moisture getter in the same material. This type of material has been thoroughly investigated under government sponsorship.[6]

Particle

Particle getters are usually designed as a multiple function system. A common multiple getter, like STAYDRY™ GA2000-2 (CSPM), is a two-part dual function system that becomes very tacky when cured. It functions both as a particle and moisture getter and has been used for applications requiring PIND (particle impact noise detection) testing and increased operating life in hostile environments. Such getters meet or exceed the limits as stipulated in MIL-STD-883D, method 5011.3. Many particle getters can also be printed on lids or needle dispensed. Particle get-

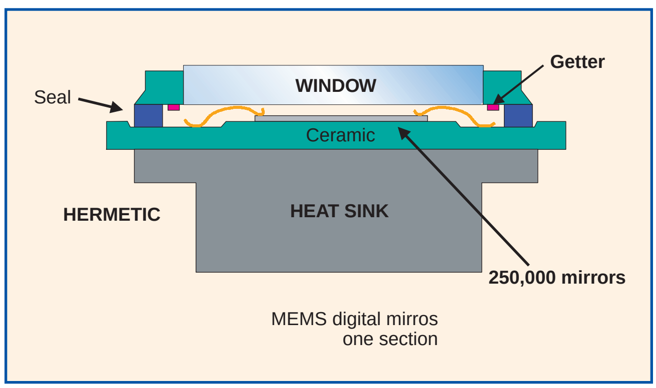

FIGURE 5: MOEMS package with getters.

ters appear to be valuable for mirror arrays and other movable MEMS devices. Combination moisture-particle getters are now being used for MOEMS.

Quasi-Hermetic Packaging?

A recent NSF-sponsored MEMS workshop (Orlando, FL, Nov. 6, 2000) discussed the various issues for packaging. Packaging cost is a high concern. The possibility was raised that getters could enable lower cost packages that are not fully hermetic. Texas Instruments suggests that a quasi-hermetic package using polymer adhesive sealing may be adequate for optical mirrors if a sufficient level of getter is employed.[7] This is one area that needs more work, and this could come from universities especially if there is government support. The NSF workshop expects to publish findings in one or more journals in the near future.[8]

Conclusions

MEMS has become a very hot technology in the last year but there are a host of issues that require economical technical solutions. Getters will play a key role in MEMS and MOEMS packaging. Dual-purpose moisture-particle getters appear ideal and are already used in some optical MEMS commercial products. More work needs to be done in this area, especially for quasi-hermetic packaging. A getter may enable lower cost packaging such as adhesive sealing or even plastic packaging. ■

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