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When Will MEMS Switches be Ready for Commercial Products?

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Opinion

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Introduction

Microelectromechanical systems (MEMS) and advanced microsystem devices have matured significantly over the last 20 years and are currently used in automobiles, cellular phones, printers, and overhead projectors.[1] MEMS switches are viewed by many as paramount for next generation radio frequency (RF) circuits and applications due to their extremely low power consumption (i.e. ~ 0 W for electrostatically actuated devices), small geometries over conventional technologies, and superior RF performance (i.e. low insertion loss: ~ 0.2dB and high isolation: 20-30dB).[2] In addition, metal contact micro-switches have great potential for a wide variety of applications due to their broadband operation (i.e. DC-40GHz). The RF MEMS switch, however, has not yet made it to "prime time" due to its perceived limitations in both performance (i.e. stable electrical contact resistance) and reliability (i.e. lifetime). Let me explain the perceived limitations and how I see a way forward to commercialization. First, the original specifications for RF MEMS switches were < 1dB insertion loss and $>1\times10^{12}$ switching cycles. I believe these specifications were originally based on using RF MEMS switches to replace transistor switches onboard satellites. Unfortunately, this original specification has become the "gold standard" for all applications. Next, the majority of RF MEMS switch researchers have primarily focused on either searching for the "holy grail" electrical contact material or on designing innovative, high contact force, mechanical switch designs (i.e. actuators). Both of these approaches are attempts to "engineer away" poor performance and reliability with either a special contact material or a better actuator. Unfortunately, most of these efforts have done little to actually improve micro-switch performance and/or reliability. As of today, I am aware of only one viable company that is pursuing the manufacture of micro-switches and several companies that have gone out of business.[3] There are, however, a few companies that have in-house research projects to develop micro-switches for their own products.[3] I believe the way forward to commercialization MEMS switches is to first study the fundamentals of micro-contact physics and thin film metallurgy in a meaningful way. What does this mean? First, as a community MEMS switch researchers need to focus on the root causes of device failure not just avoiding failures. For example, when studying the electrical contact it should be decoupled from the mechanical switch design so that the micro-contact physics can be studied directly. The results of these fundamental studies could then be used to design micro-contacts suitable for micro-switches.

This is how macro-switch designers study switching phenomena. Next, as a community MEMS researchers need to engage with Industry to obtain realistic specifications for true applications. Are one Trillion switching cycles truly required for all applications? Cell phones? Automotive? Relays? Certainly not, but if you ask an integration engineer from the cell phone or automotive industry they will cite "poor reliability" (i.e. < 1 Trillion cycles) as the primary reason for not using MEMS switches in these applications.[3] Recent studies in micro-contacts include various dedicated test fixture approaches including: actual MEMS switches, atomic force microscopes (AFM), scanning tunneling microscopes (STM), and nanoindentors, have been used to collect the micro-contact data (i.e. contact resistance and contact force). Although these new approaches are encouraging, each of the above methods has severe limitations. For example, MEMS switches work well for lifecycle testing but not for measuring contact force which must be inferred through modeling. Additionally, AFM/STM and nanoindentor –based test fixtures allow direct contact force measurement but at extremely low cycle rates (i.e. 10-100Hz). Another restriction is the inability to test contacts in controlled ambient environments for contamination control.[4–9] In my group, we study micro-contacts using a dedicated novel test fixture, housed in a controlled N_2 ambient environment, capable of both "hot" and "cold" switched initial contact and cycled contact testing up to 3KHz. Contact force and resistance data are simultaneously collected, in-situ, while applying a calibrated external µN load to a MEMS micro-contact support structure (i.e. not a switch) configured as a Holm cross-bar test.[10] Using this unique apparatus, we have explored and characterized the performance and reliability of novel material micro-contacts such as: Au-Au, Au/CNT composite -AU, Au-Ru, Au-RuO_x, etc. In addition, we have studied engineered micro-contact geometries and pairs consisting of hemispherical upper contacts landing on either planar or 2D pyramid lower contacts. Additional studies in low-frequency AC, external circuit loadings, and DC polarity test have also been conducted.[11–15] In summary, it's the opinion of this author that MEMS switches will continue to not be commercialized until the MEMS research community fully engages with Industry to obtain realistic specifications for real applications. Once realistic specifications are known, it is incumbent on MEMS researchers to conduct worthwhile, knowledge generating, studies to better understand the fundamentals of micro-contact physics.

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Conflict of interest

The author declares no conflict of interest.

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