

Standard Open Tool Packages for MEMS Enabled Products

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A well recognized commercialization barrier for MEMS enabled products has been and continues to be packaging. This is a significant technological problem in the MEMS industry, and has resulted in custom packaging for each application, leading to higher overall package cost, which may be as high as 80% of the product cost. Packaging of MEMS components differs significantly from the packaging of microelectronics, which is well established, primarily because unlike microelectronics, the functional specification of the MEMS chip is critical to the design of the package. Industry experts also recognize that a “lack of attention” may be a contributing factor to the overall problem both within organizations, as well as externally by industry vendors and suppliers. Today there are new options for reducing MEMS packaging costs and ultimately bring MEMS devices to market faster.

MEMS PACKAGING CHALLENGES

While MEMS’ manufacturing processes are somewhat similar to ICs, the functionality of these systems is very different and present unique challenges for MEMS packaging. In microelectronics, open tool packages may be used for several chip designs as long as they meet size and connectivity requirements, which is quite unlike MEMS packaging. However, open tool packages serve as very useful starting points for MEMS packaging concepts and combined with wafer level or die level packaging or encapsulation solutions, could offer a low-cost path to MEMS product commercialization.

Microsystem packaging involves multiple layers of interfaces enabling connectivity from the chip to the outside world. It is well established that any unforeseen effects of a package on a MEMS device can ultimately inflate product development cycles, time-to-market and production costs. For standard off-the-shelf packaging to be viable in the MEMS industry, multiple effects must be considered at all levels, starting with the MEMS device, chip, module, card, board and finally frame gate. MEMS typically contain moving parts that are very sensitive to package effects, and often may need to interact with the outside world in some way depending on the application. In the working environment, packages need to provide a controlled environment that is often hermetically sealed to protect against environmental stresses and corrosion, as well as mechanical and electrical isolation to improve device robustness. For all these reasons, the complexity of MEMS packaging becomes highly dependent on the specific application, forcing designers to either consider these effects seriously and come up with unique solutions or go back to the drawing board. Additionally, MEMS devices are fragile mechanical devices that need to be protected from damage during wafer level processes such as dicing and cleaning. Wafer Level Encapsulation (WLE) technologies as a post-processing step in a manufacturing flow is a low cost technique for increasing yield and is more widely used today in the MEMS industry. In certain applications, WLE is sufficient as final packaging of the device prior to use.

CO- DESIGN OF MEMS & PACKAGING

The complex 3D mechanical (suspended) nature of MEMS makes them highly sensitive to their package environment, significantly more so than conventional IC

products. Currently, MEMS design is typically focused on the component level using specific MEMS CAD tools that address the inherently complex device design. Although some techniques exist that allow for package-device co-design¹, they assume that decisions about the kind of package, size, materials etc. have already been made, which is typically not that straightforward a task in the first place, given the diversity of applications. Product design groups rely heavily on the expertise of package designers (with experience typically from the micro or optoelectronics industries) to *choose* the package based on a variety of factors like cost, availability, customization, etc., and then to *design* the package² based on specifications of the MEMS device. This has typically resulted in product developers postponing package selection until after the initial device design has been completed, when design modifications are time-consuming, complex, and costly to rectify. This has also led to inefficiencies in the design process due to the time involved per design iteration. Although the industry is starting to recognize the specific differences between MEMS & IC packaging, and the need to protect the MEMS during fabrication, addressing these challenges often requires access to industry specific tools and know-how that often resides with package suppliers. It is important for suppliers to share enough data with designers to overcome these barriers.

LOWERING MEMS PACKAGING CO-DESIGN BARRIERS

¹ Reference: Bart, S., et al., *Enabling MEMS Package-Device Co-Design through extraction of compact models*, InterPak, Hawaii 1999

² Currently package designers use a variety of FEM based tools for addressing the thermo-mechanical and/or thermo-fluidic aspects of the package design.

Until now there was no simple way of sharing detailed package design data in the early stages of the MEMS design process. Recent availability of a set of standard open tool IC packages within an existing MEMS CAD tool environment will deliver to designers detailed package design data in a easy-to-use, accessible environment. The package CAD data is supported by the package supplier directly and will be available in the form of a library of different packages of various size and type, and which are easily modified to custom designs.

Today, new ground has been broken with the collaboration of a top package supplier (Kyocera) and a leading MEMS design tool provider (Coventor). For the first time, these two groups are offering standard package libraries that may be used to select and analyze the effects of a package on a MEMS device in a single environment. The goal is to preempt some of the issues discussed earlier, arising from MEMS packaging, and ultimately speed their commercialization.

Kyocera is a world leader in technology based information systems, telecommunications and consumer based electronics, and it is also the dominant supplier of electronic packaging for the semiconductor industry with extensive standard open tool ceramic packages. Ceramic technology provides superior performance because of its mechanical strength, thermal conductivity and heat durability (for harsh environments), and cost-effective enough for the consumer market. Through the availability of open tooled packaging solutions from Kyocera, (both package and MEMS) designers now have significantly more choices for initial package selection i.e. in terms of chip size,

number of electrical connection, etc., and to consider the effects of packaging early in the design phase. With access to the package geometry and materials data in a MEMS design environment, both package and MEMS designers could communicate design information more effectively. For example, package selection from among a variety of package types, performance based design (thermo- mechanical, or electrical effects), modification of package CAD data to specific microsystem requirements, system level optimization, etc. could enable shorter design cycles, reduced risk and faster time-to-market. Kyocera's packaging libraries are now available bundled with CoventorWare[®], the industry's leading MEMS design software suite. The availability of these package libraries to such a wide group of designers, at no additional cost, will help accelerate product development considerably.

PACKAGE LIBRARY CONTENT

For MEMS design, packaging data is best introduced in the form of 3D models. The library allows designers to create the 3D geometry from supplied data, modify the existing provided geometry or import it in standard format³. A complete description of the materials used in each package type is also available. Since a variety of views exist for the package it is possible for the designer to modify the package geometry and material properties completely, thereby allowing for custom package design. These custom designs can be directly sent back to Kyocera for feedback or even prototyping.

The package library contains models of a variety of open tool packages types including surface mount devices (SMD), Side Brazes (S/B), pin grid arrays (PGA), Cerdips (C-DIP), leadless chip carriers (LCC), flat packs (F/P), and chip scale packages

³ Standard formats such as DXF, IGES, STEP are supported

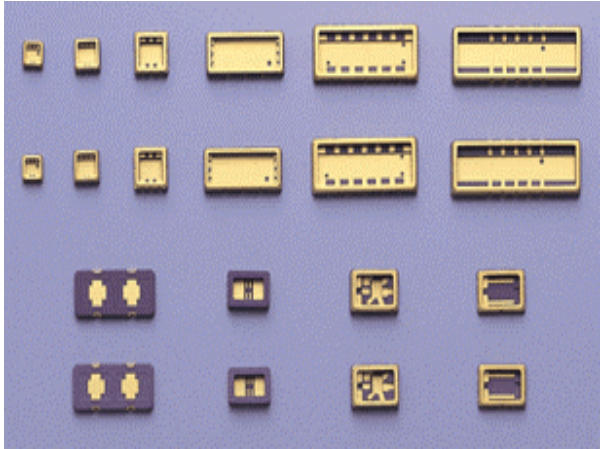
(CSP). Each package model includes material and geometry data (and is also available pre-meshed) as well as the ability to modify all these parameters. The library is embedded within the existing CoventorWare interface, for ease of modeling and analysis, and also contains detailed documentation for user consideration.

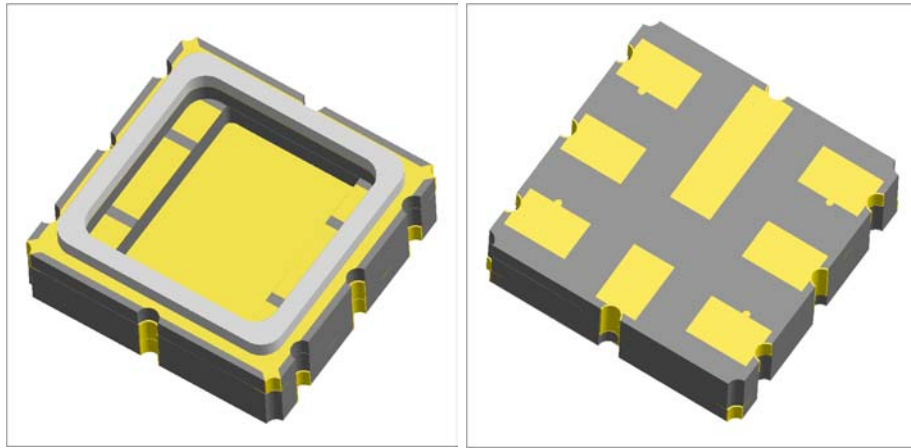
During the design phase, the availability of physically detailed and accurate package models (i.e. geometry and material properties), allows a package model or several models to be considered and then co-simulated with the MEMS device to predict a variety of typical package effects, such as coupled thermo-electro-mechanical or thermo-fluidic performance or coupled RLC analysis. In the working environment, packages experience a variety of loads such as high-G loads, shock impact, electrical currents or fields, operational temperature ranges, ESD, etc. and it is of critical importance to be able to understand the effects of these loads on the operation of the MEMS device. Additionally, the designer needs to understand the effects of other external stimuli such as noise, and vibration. It is also important for designers to be able to directly observe the coupling between the various sub-systems - MEMS, IC, and packaging. System level modeling (through standard tools from Synopsys® or Cadence®) is a very powerful technique to allow the MEMS product group to couple the various sub-systems in a single environment. Standard packages from the library could also be converted directly into macro-models that are available to system level descriptions of the product, thereby allowing for a higher level of optimization of the product.

CONCLUSION

The ability to bring in standard open tool packages for consideration early in the MEMS design phase, offers product development groups a unique way for the package and device designers to communicate within the same CAD environment to solve problems that are unique to MEMS technology. The ability to successfully import, build, analyze and troubleshoot packaging effects on MEMS devices early in the design cycle enables designers to limit product risk and reduce cost. Further it offers package designers a path to start with an available package and make changes with the microsystem in mind, and further to feed those changes directly back to the supplier for custom development if necessary. This new capability would ultimately help bring MEMS enabled products to market faster and at a lower cost.

FIGURES





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