

Design for Micro & Nano Manufacture

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"Manufacturing starts with the design". This statement holds especially true in the case of micro and nano technology (MNT), as there are a range of manufacturing related difficulties that can be simplified by either design enhancements or the integration of additional functions. This design for micro & nano manufacture (DfMM) methodology is still immature and is one of the main reasons why the commercialisation of MNT based products is still severely limited despite a range of impressive research programmes, design innovations and initiatives across the globe.

Some of the key problems that affect manufacturability are now widely acknowledged and include difficulties in developing economic production test strategies and efficient packaging and assembly solutions. Guaranteeing robustness and reliability is extremely difficult due to complexity and the heterogeneous nature of most MNT based products. Improved design support is becoming a key commercial requirement with pressure on tool vendors to optimise models aimed at providing the designer with the means to predict the impact of second-order effects on the design, and verify end-use stability and subsequent reliability, especially in aggressive environments.

The need to solve these issues in MNT is hampered by the shortage of multidisciplinary, skilled engineers, and the need for major advances in simulation and modelling technology that handles hierarchical heterogeneous designs. Furthermore, many typical applications of micro & nano system technologies require very high reliability, but suitable test methodologies, standards and instrumentation are often missing. Time-to-market targets for most MNT products will therefore only be achieved if these so-called "back-end" issues are addressed early in the design cycle.

During the last few decades DfMM issues have been tackled by manufacturing companies usually only when a severe problem existed with issues such as reliability, yield or manufacturing cost. On the academic side, DfMM has been a topic considered not very exciting for PhD theses. Funding agencies worldwide have often focused on process developments and sometimes on products, but not often on the whole MNT "design-to-manufacturing" supply chain.

This has changed! Companies -small and large- as well as funding organisations and universities now acknowledge the importance of an overall DfMM approach all along the development chain:

- Industrial companies have launched programmes to imple-

ment an integrated view on DfMM. Companies in the US - even the large ones - discussed their problems and approaches to solve these in rather detail during the MEMS Industry Group (MIG) METRIC meetings in 2003 (Focus on Reliability) and 2004 (Accelerated Lifetime Testing). From these meetings, recommendations were given to DARPA (on funding needs) and further joint activities formulated to MIG for initiation and coordination. In addition to the authors of this article, a few European companies attended METRIC 2003 and 2004 and found the discussions really useful.

- The European Commission is funding a Network of Excellence under its 6th Framework Programme. The project "Design for Micro and Nano Manufacture (PATENT-DfMM)" has the mission to establish a collaborative team to provide European industry with support in the field of DfMM with a view to ensuring that problems affecting the manufacturing and reliability of products based on MNT can be addressed before prototyping and production. The project aims to initiate integration and growth in DfMM skills and capability with the long-term objective to set-up a financially sustainable organisation that provides a DfMM service to European Industry.
- Providers of Electronic Design Automation (EDA) tools and providers of tools for design, modelling and simulation in non-electronic domains (mechanical, fluidic, optic, etc.) are focusing more on the development of interfaces and modules towards a seamless "design for manufacturing" tool flow for the future. Experts agree that this seamless flow will remain a dream for some time to go, but improvements are already clearly visible from the tools of the early days of MEMS, many of them only to be used by PhD level experts following an intensive training. Industrial approaches to DfMM, examples of tool providers' views and a

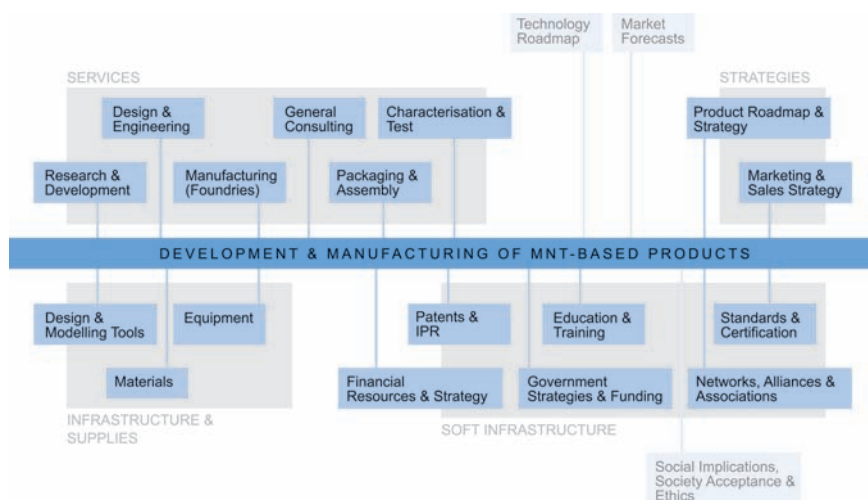


Figure 1: Micro & Nano Technology Supply Chain (source: www.enablingMNT.com)

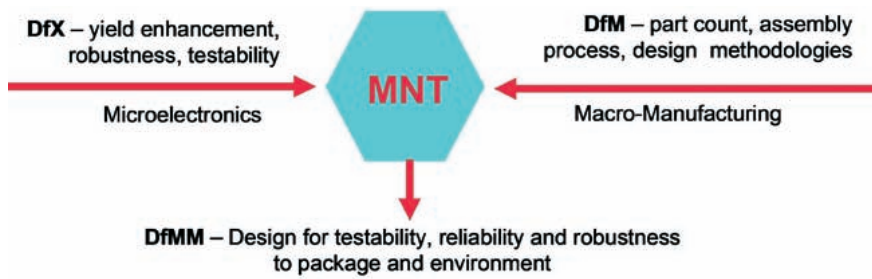


Figure 2: A new DfMM methodology for M&NT based products (source: www.patent-dfmm.org)

report on the MIG activities are described in more detail in other articles in this MST News issue.

This article gives an overview on the "Design for Micro and Nano Manufacture (PATENT-DfMM)" project launched by the EC in 2004. PATENT-DfMM is a reactive initiative whose objective is to realise the vision of providing innovators, be they members of small companies, universities or multinationals, with a "predictable" route from MNT based product concept to manufacture through a cross-organisational service. This will be achieved by establishing in the medium- to long-term a new concurrent engineering or DfMM methodology for MNT based products that provides designers with the means to design for performance, testability, robustness and dependability competitively, whatever the operating environment.

To achieve this vision, major technical challenges need to be solved that are both technically difficult and require workable cross-disciplinary teams. PATENT-DfMM will address these challenges by:

- Providing experts with the incentive and resources to cooperate in solving key technical challenges in the fields of modelling and simulation, test engineering, reliability engineering and package engineering.
- Encourage cooperation across these fields and application domains to help realise a new DfMM methodology for MNT based products.
- Realising critical mass of expertise through the formation of a "virtual institute" across Europe that develops, coordinates and delivers training programmes for internal staff and the community. It will also disseminate know-how to peers working within related engineer-

ing disciplines and promote awareness and interest in the engineering science associated with

the manufacture of MNT based products.

- Establishing a durable integration of researchers in key technical disciplines that provides a one-stop-shop service to industry and over a 4-year period, integration of these teams into a "DfMM services" organisation.

The realisation of a DfMM methodology within the MNT field has already been identified as crucial by expert teams preparing MNT roadmaps in

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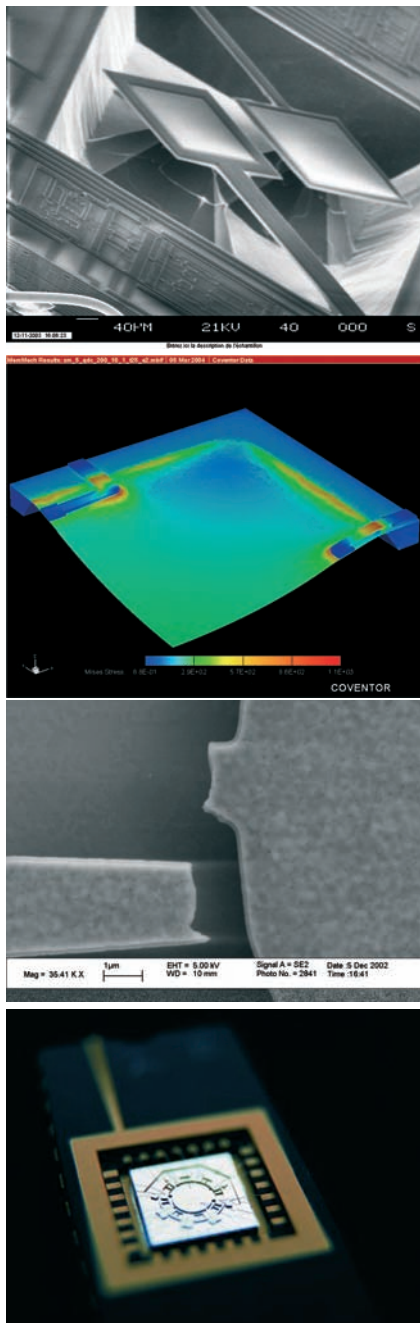


Figure 3: DfMM Photo Gallery (Source: LIRMM, ISLI, POLIMI, QinetiQ - www.patent-dfmm.org)

both Europe (NEXUS) and the USA (MIG). The implementation of this approach requires an extension of the strategies used within the microelectronics industry, where EDA vendors support yield optimisation and Design-for-Testability insertion and are able to accurately model designs and both verify design integrity and testability prior to manufacture. The extension of the methodology to MNT is, however, extremely complex due to the integration of functions operating in the mechanical, optical, fluidic or bio-chemical domains and the need for the process to be ex-

tended to the assembly level in the system hierarchy. It is therefore clear that the design for manufacture strategies adopted in the microelectronics industry needs to merge with elements of the strategy used in conventional macro-scale manufacturing as illustrated in Fig. 2.

State of the art in MNT is therefore well behind the DfX strategies researched within the microelectronics community as model-based testability optimisation and verification procedures are not yet in place properly formalised and the application specifications are generally far more challenging than for microelectronics devices. It is therefore clear there is an absolute need to create a new multi-disciplinary technical community that integrates design, test, package and reliability engineering technologies.

PATENT-DfMM must overcome a number of structural issues to create the environment for real progress to be made. Firstly, experts working in the key MNT disciplines of modelling & simulation, design-for-testability, package engineering and reliability engineering do not tend to be concentrated in the main technical centres and mostly focus on industrially led projects that aim to solve problems related to specific products. There is therefore an initial objective to integrate these researchers into clusters and provide incentive and resources to encourage these teams to work cooperatively towards the generic, "difficult" challenges that support DfMM goals. Secondly, only a small number of teams cross the divide existing in the MNT community between design, modelling and simulation, test engineering, package engineering and reliability engineering. PATENT-DfMM will provide a structure to support a radical increase in interaction between these research areas and a route for integrating advances into a DfMM methodology supported by the EDA industry. The project is guided by an Industrial Advisory Board (IAB) to ensure orientation towards applicability in industry.

In summary, the main objectives of the PATENT-DfMM project are to:

- Re-structure the European DfMM Community by creating new collaborative virtual laboratories pro-

viding industrial services in:

- Design-for-test engineering
- Reliability and characterisation engineering
- Packaging engineering
- Modelling and simulation technology
- Create a commercial industrial support service in DfMM technology
- Accelerate the output of trained professionals in DfMM engineering
- Network the key equipment facilities and improve academic and commercial access to core capabilities

The technical work is structured into four Task Forces:

The **Task Force on Design for Testability** of MNT based systems works on methodologies that have the potential to improve the testability of these systems over the complete life cycle. Main focus will be on self-test, condition monitoring, fault tolerance, as well as test support tools and methodologies. The whole chain from design through development and in-service test will be covered.

The aim of the **Modelling & Simulation Task Force** is to support the process of robust design, packaging and assembly of the next generation of MNT based products. It will launch a collaborative service to industry in the form of a virtual laboratory by integrating modelling experts working in different physical domains with the expertise from the other PATENT-DfMM task forces. Close cooperation with EDA companies and design houses will be established.

The objective of the **Reliability & Characterisation Task Force** is to increase awareness of reliability issues amongst designers, and assist them in integrating "design for reliability" techniques into their design flow. This will be achieved by providing information on material properties, failure modes, reliability test modules, sensitive design rules, reliability prediction models, and on the effect of packaging on reliability. Objectives are also to spread knowledge amongst partners and make instrumentation accessible.

The **Package Engineering Task Force** aims to link the physical domains of micro/nano structure design and package design in terms of engineering issues, such as Failure Mode and Effect Analysis (FMEA), procedures for reducing impact of stress and environment, and stress and assembly process monitors. Methods of low-cost testing for integrity utilising in-systems functions together with methods of modelling a package-environment-device interaction need to be taken into account.

PATENT-DfMM is supported by an educational programme addressing DfMM topics in industry and academia. This combines training courses and educational initiatives that already exist for DfMM, but also develops new ones that are needed to lower the barriers to commercialisation for the next generation of micro & nano technology based products.

PATENT-DfMM publishes a bi-monthly free E-mail Newsletter. Please register at www.patent-dfmm.org.

A DfMM Summer School will take place in Montpellier (F), 5-7 Sep 2005.

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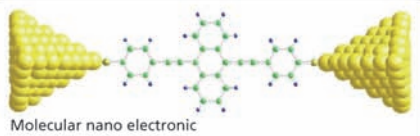


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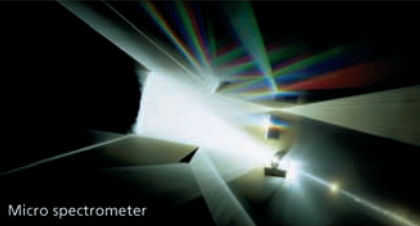
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