

1. Study Context

For several years now, 450mm wafer processing has been under discussion but apart from work on setting the standards and some prototype equipment, little had actually emerged. Indeed much discussion focused on whether the industry could actually afford to make this transition, how much it would cost and who would pay for it. The European Commission thus decided to undertake this project to determine the future, if any, of 450mm processing and the effect this would have on Europe.

As such, the EC awarded a contract to DECISION in partnership with Future Horizons to undertake a study on the activities required to support research and innovation in the field of advanced semiconductor production and measures necessary to attract investments and to support advanced research infrastructures, prototyping and early nanoelectronics manufacturing in Europe with particular emphasis on 450mm manufacturing, including:

- An assessment of the role of the European Commission and Governments of Member States and Regions for the establishment of 450mm manufacturing capabilities, including related value chain aspects, and overall their role in keeping semiconductor manufacturing and advanced nanoelectronics technologies in Europe
- An analysis of potential links between newly established 450mm manufacturing with existing semiconductor manufacturing capabilities and their likely impact on them both at the prototyping and high-volume level

The study has been conducted from January 2011 to February 2012 and involved a wide range of interviews with senior industry executives not only in Europe but also in the US and in Asia.

2. 450mm Transition Status And Impact

At the time of commissioning this study, there was still some scepticism among the industry regarding the 450mm transition. This climate has changed by March 2011 following Intel and TSMC's near simultaneous announcements that they intend to roll out 450mm wafer technology in their latest fab plants, quickly joined by Samsung, Global Foundries and IBM to form the G450 Consortium in Albany.

The largest SC suppliers promote the transition to 450mm wafer size in order to keep up with the 10% annual growth in wafer fab capacity demand while maintaining the number of fabs under control since a 450mm fab has 2.25 times the output of a 300mm fab. The 450mm transition is also expected to deliver a 30% cost reduction thus providing to 450mm wafer fabs a decisive competitive advantage over 300mm.

First hesitant and even reluctant, the equipment and material industry is now asking to be fully associated with the transition and there is a tacit acceptance that any technology and process issues related to the 450mm development will be solved in due time. It is however highly unlikely there will be parallel development on 300mm ITRS node development once 450mm is in full production before the end of the decade.

Since the 450mm transition will very likely be the final wafer scale up for the industry, it will define the geographical locations of the next (and perhaps final) ten to fifteen most advanced semiconductor production areas worldwide. 8nm is likely to be the first node only available on 450mm platforms for volume production meaning "Post CMOS" technologies will be exclusively developed on 450mm platforms.

In addition to the most advanced CMOS technologies also called More Moore (MM), the 450mm transition will also impact the existing SC manufacturing infrastructure competitiveness to different degrees and timescales. Within a 10 year period, 200mm fabs

will experience the earliest and strongest impact since 450mm fabs will generate 300mm spare capacities that will seek to penetrate 200mm markets quite similarly to what happened to 150mm fabs following the transition of advanced CMOS technologies to 300mm. Within a 15 to 20 years period, mature technologies could also be manufactured on 450mm and although it is possible some product categories may never be produced in 450mm, no product should be discounted provided the volumes are there.

3. EU SC Position With Regard To 450mm

Europe SC industry still holds world leaderships in R&D and IC design technologies with world-class research institutes, IP suppliers and Universities but also in equipment and material industry with market leaders in key equipment and process areas. Other European strengths include utility and facility engineering. However the situation is not a good one for IC production since Europe has missed the 300mm transition and the European SC manufacturing base is now mostly composed of 200mm fabs with only few 300mm sites. Indigenous IC suppliers focus on their leaderships in advanced products based on more mature technologies (More than Moore – MtM) that will continue to be manufactured on primarily 150mm and 200mm wafers for some time to come. Coincidentally, Europe indigenous IC device manufacturing activities failed from 12% of worldwide investment in 2004 to only 4% in 2011. Europe is now at a crossroads.

The 450mm highlights divergences of views and priorities across the European SC supply chain since there is currently no commitment from European IDMs to 450mm with only one firm incorporating 450mm into its long-term strategic plan. On the contrary, equipment and material suppliers consider 450mm as an opportunity to secure their leaderships and grow their business. There is also the underlying fear that 450mm technology support in Europe would be to the detriment of current 300mm necessary development and vice versa.

However, this passionate debate tends to ignore the fundamental reality that it is only a matter of time before today's leading edge MM will form the base for tomorrow's MtM. The fact remains that the transition to 450mm will impact all levels of the European SC supply chain, from SC fabs suppliers (facilities, equipment & material suppliers) to IC device manufacturers and designers, albeit with different timescales and to different degrees, depending on companies activities and portfolios. But nonetheless, all will be impacted.

Europe will lose advanced and competitive SC manufacturing infrastructure without a European long-term industrial vision guiding and enabling the coordination of all stakeholders. Such a long-term vision shall not oppose 300mm or 450mm but rather consider both in parallel as part of an advanced manufacturing continuum, taking into account all the stages of the SC supply chain.

The fact remains that the 450mm transition will require very significant levels of investment and funding compared to the investment patterns for 300mm. Once such a transition has been realized, funding will also be necessary to attract wafer fab investment up to \$10 billion depending on fab configuration. The capability of Europe to first play a role in the transition and ultimately host 450mm fab(s) will thus be conditioned to two factors, namely an industrial commitment to 450mm in Europe and a significant degree of coordination between all funding instruments available at local, national and community levels.

4. Towards An Integrated European 450mm Strategy

The study analyses in detail the cost and impact of three 450mm scenarios for Europe based on the amount of resources available, the timing and the industrial target. This includes the innovative concept of a 450mm joint-fab model in Europe between IC device suppliers in true

partnership with equipment & material suppliers, initially targeting MtM products but providing a European bridge to MM technologies in due time.

Given the various possible scenarios and impacts, an ideal integrated approach towards a real 450mm European strategy can be delineated as follows:

Phase 1: 2012 to 2017

- Objective: Support equipment and material suppliers transition to 450mm
- Output: Basic research complementary to G450C activities and pre-production tools for European equipment suppliers leveraging the strength of existing European cooperation network
- Instruments: Combination of existing cooperative R&D programmes and a European 450mm pilot line (450E)
- Cost (public funding): Over half of the current budget for SC cooperative R&D in Europe over the next five year (US\$150 million per year)
- Funding mechanism: Existing instruments (ENIAC/CATRENE) with an increased contribution by EC together with new forms of funding and rules (see KET Report: pilot line funding) in order to increase the total budget to such levels that it will be possible to perform both 300mm necessary development and 450mm investment in parallel

Phase 2: 2016 to 2020

- Objective: Support the development of 450mm production facility(ies) either based on Foreign Direct Investment in a MM fab and/or a jointly-owned MtM fab
- Output: This depends on the fab typology (MM vs. MtM) but will secure long-term European leadership and access to the most advanced SC technologies. To ensure an integrated approach, Phase 2 needs to be undertaken in a timely manner to provide an industrial environment for the equipment/material suppliers to follow-up on their investments made in Phase 1
- Instruments: Grants, tax concessions, special loans and infrastructure investments, etc. In the case of a joint fab structure this could also be based on some kind of European-level funding
- Cost (public funding): Total subsidies in the range of US\$1 billion to US\$3 billion depending on the fab configuration including both up-front subsidies and on-going incentives cumulated over the life of the fab (up to 10 years). This requires setting the right investment framework to favour Foreign Direct Investment in state-of-the-art MM 450mm at national level and/or defining a common European strategy between EC and the parties involved for the development of a MtM 450mm joint fab

Phase 3: 2020 & beyond

- Objective: Continue to ensure attractiveness of Europe to SC manufacturing investment
- Output: Support a pilot line for the post-CMOS era and start the next innovation cycle. In a truly integrated approach this would ideally utilise the previously developed 450E infrastructure
- Instruments: On-going 'maintenance' support for the EU-based 450mm infrastructure together with similar Phase 1 instruments to develop the post-CMOS technology and associated equipment and materials
- Cost: Similar in relative size to Phase 1 for 450mm; prohibitive, if even do-able, without the successful implementation of Phase 1 and Phase 2 given that by 2020 450mm will be the only viable platform for advanced SC development

5. Conclusions

Europe is currently leading the world in MtM technologies but this leadership is at risk being dependent on an indigenous semiconductor production platform that is predominantly 200mm and smaller wafer-size based. This is not currently a major disadvantage but by 2020 it will be once 300mm MM production migrates to 450mm technology pushing a sizeable part of today's 300mm MM production to MtM, as is anticipated.

Europe failed to capitalize on its strength during the 300mm transition, but 450mm could turn into a genuine opportunity to regain the position it once held in SC manufacturing by securing a complete SC supply chain and making sure that the most advanced SC technologies continue to be manufactured on European soil.

It could start in the short term with a five-year programme to urgently set up the 450E pilot line in Europe to support the transition of the European equipment & material suppliers to 450mm and coordinate with the US-led G450C initiative in Albany. From a chip production perspective, the opportunity of a joint 450mm MtM fab (Eurofab450) between Integrated Device Manufacturers and a private 450mm MM fab should be investigated and progressed in parallel to their natural conclusion.

As such, the integrated approach outlined above represents an ideal European opportunity, not only to maintain its current 'MtM' world lead but to also enable it to re-enter the 'MM' manufacturing opportunity, a key part of the KET strategic vision.

Whatever the outcome, every effort must be expended by the European Commission and national PAs to ensure that all potential locations and especially the current most advanced manufacturing centres in Europe remain favourable places for chip companies to operate in. As already proven in the past, an admittedly large subsidy in state-of-the-art 450mm semiconductor manufacturing will leverage a very large inward investment and Return On Investment for Public Authorities including multi-billion dollars of exports for Europe on an annual basis.

High tech industries can only close competitive gaps during technological shifts. The 450mm shift is one of them and most likely the last one for the semiconductor industry: the European semiconductor industry is at a crossroads. The 450mm transition is a unique opportunity to launch a European industrial policy, building on its strengths (R&D, equipment & material, cooperative development) and an increased level of coordination to preserve the remaining manufacturing base in Europe and protect its innovation power in the future.