Lithography technology and trends for More than Moore devices
Advanced Packaging & MEMS devices

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Biography

Amandine Pizzagalli is in charge of equipment & material fields for the Semiconductor Manufacturing team at Yole Développement after graduating as an engineer in Electronics, with a specialization in Semiconductors and Nano Electronics Technologies. She worked in the past for Air Liquide with an emphasis on CVD and ALD processes for semiconductor applications.

Abstract

Lithography requirements for Advanced Packaging & MEMS are very different compared to mainstream semiconductor industries' needs. Even if the market entry barrier is much lower in the "More than Moore" market, customer adoptions needs are higher in the packaging area with respect to resolution, overlay, sidewall angle, and depth of focus (DOF), wafer handling for wafer bow and backside alignment.
Key technical trends, requirements and challenges regarding the lithography technologies will be addressed in this paper.
In addition, more insights on the current and emerging lithography methods for More than Moore devices will be included, as well as market forecast, competitive landscape of the major equipment suppliers addressing these fields.

Keywords—Lithography, resolution, RDL, wafer warpage, Depth of Focus (DOF), Advanced Packaging, MEMS, More than Moore

Introduction

The photolithography market for Advanced Packaging & MEMS is very different compared to the "More Moore" or mainstream semiconductor industry and exhibits very complex technical specifications. Indeed, customer adoptions requirements are much higher in the packaging area as well as MEMS & Sensors devices with respect to resolution, overlay, sidewall angle, and depth of focus (DOF), wafer handling for wafer bow and backside alignment. Resolution required in the front-end differs from the resolution required for Advanced Packaging which is in the single digit micron range. The current minimum resolution requested is below 5 µm for some advanced packaging platforms, like 3D integrated circuits, 2.5D interposers, and wafer level chip scale packaging (WLCSP). A lot of development is being made to reduce overlay issues due to shifting dies and obtain vertical sidewalls for flip-chip and WLCSP. In addition, higher DOF in a range of 10 µm is needed to handle thicker resists as well as high wafer topography. High DOF is also needed for MEMS projection systems and for some MEMS devices including DRIE steps with high resist thickness.

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Advanced Packaging has very complex technical specifications which differ from those associated in the front-end area.
Warpage handling as well as heterogeneous materials represent big challenges to photolithography. Due to aggressive resolution targets in Advanced Packaging, performance must be improved.
In addition, accurate layer-to-layer alignment is required for some MEMS manufacturing devices where misalignment features can lead to lower performance such as gyroscopes and micro-mirrors. Similarly, high DOF is required for projection systems and MEMS applications where high resist thickness is needed to enable DRIE process steps.

In the case of Advanced Packaging, stepper and mask aligners are today the two main lithography technologies used in high volume manufacturing. Mask aligners offer full wafer exposure and can process wafers very quickly. They have small throughput advantage and are the cheapest process compared to other lithography technologies. However, the systems have overlay limitations as they cannot handle distortion and die shift which need to be addressed for some Advanced Packaging platforms. On the other side, steppers are much more expensive but they have the ability to pattern small features at a resolution close to 2 µm with the best overlay. Thus, from lithography technologies point of view, steppers are mandatory for TSV packaging since it is based on very tight pitch between bumps with future needs of 20 µm micro-bumping capabilities. Bumps are scaled down to achieve better resolution for very high-level wiring density at the RDL level. General lithography requirements for TSV packaging are summarized in Figure 1.

Although mask aligner and stepper technologies are the most mature technology available on the market for Advanced Packaging,

new disruptive lithography technologies such as laser direct imaging (LDI) and laser ablation are also emerging and could contribute to market growth in coming years by offering adequate specifications at lower cost depending on the final application and requirements in terms of depth of focus (DOF), exposure field size, resolution and cost.
Significant business opportunities in the Advanced Packaging market are therefore driving photolithography equipment demand. Given the high growth rate of this market, there is no doubt that already established photolithography players and new entrants will be attracted.
In the case of MEMS devices, mask aligners represent the majority of brand new photolithography systems sold today. However, an increased market share for steppers is expected in the coming years to reach very accurate layer-to-layer. Nevertheless, due to its relaxed specs, the MEMS photolithography market benefits from a high percentage of re-used/retrofitted equipment coming from the mainstream front end semiconductor industry.

Competitive landscape

The semiconductor industry is very often identified by its "More Moore" players, driven by technology downscaling and cost reduction. In the "More than Moore" industry the holy grail isn't downscaling any more – it's adding functionality. But it's still similar to photolithography.

The lithography market is technologically segmented with a significant gap between equipment suppliers in terms of resolution performance, cost coming from the front-end, and niche applications or back-end.

Front-end equipment vendors such as ASML and Canon provide the best tools in terms of resolution. However, they have limited DOF and therefore, are not suitable for Advanced
Packaging applications. In addition, they are typically much more expensive compared to the tools provided by specialized equipment vendors such as Veeco/Ultratech and SUSS MicroTec. On the other hand, back-end equipment is generally cheaper, but can face scaling issues as semiconductor ICs continue to shrink.

Equipment in the Advanced Packaging and MEMS industries is less complex but customer adoption needs are higher, which leads to a much broader photolithography landscape. As the photolithography market structure for these two industries is very different compared to the "More Moore", or mainstream semiconductor, industry, new entrants can penetrate these markets with a good knowledge of the technological building blocks.
Moreover, increased competition is driving acquisition between equipment vendors such as those between Veeco and Ultratech and KLA Tencor and Orbotech. These deals with help suppliers gain more value from the supply chain by capturing share in lithography equipment market.

Possible scenarios can happen including acquisitions, mergers, and joint ventures, along with their anticipated impact on the global photolithography market. Figure 2 presents some of the possible solutions that could happen in the future.

Conclusions

Lithography for Advanced Packaging & MEMS devices is considered a market with a high potential for growth as it includes many different players along the supply chain. In addition, due to the different challenges to address in the lithography processes for Advanced Packaging & MEMS devices, there are huge business opportunities in those areas which could reshuffle the photolithography equipment demand to meet the requirements in terms of performances and cost.

Illustrations

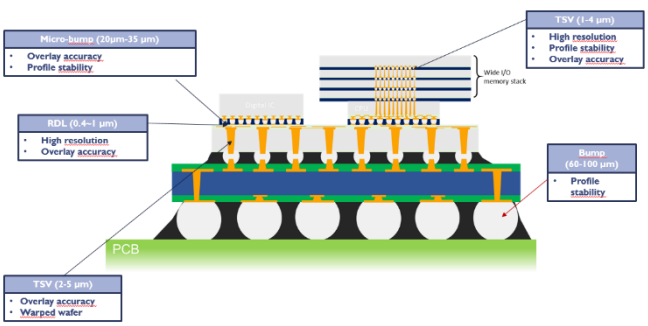

Fig.1. Lithography Requirements in Advanced packaging & MEMS

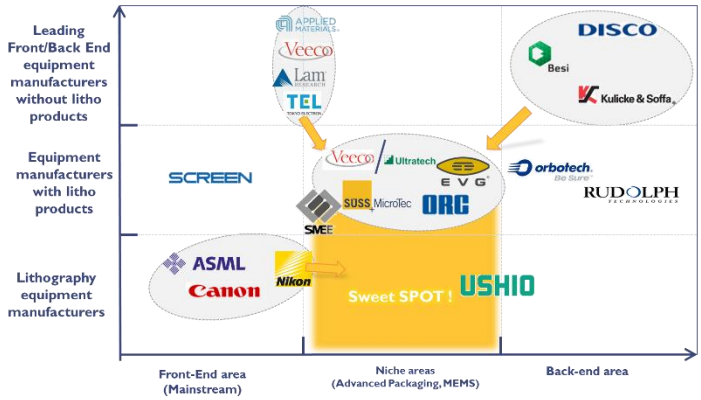

Fig. 2. Lithography player positioning: possible reshaping of the industry

References

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