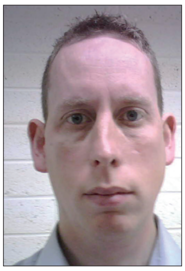
Take up of lasers in the semiconductor industry



David Gillen

Recent developments in high average power short pulse lasers have raised the awareness of their many positive processing characteristics in the context of industrial production of components with micron-scale features, such as semiconductor chips. But for an industrial application we need to look further than the processing characteristics of the laser and consider its economic attractions when compared to existing technologies; such as (in the case of semiconductor chips) Deep Reactive Ion Etching and the mechanical saw.

AILU members should be good ambassadors and keen to drive and expand laser technology in the micromachining market but we also have a responsibility to understand deficiencies as well as benefits. All of us who have an interest in this market know that laser micromachining has not been taken up as much as we thought it would have been and although the global semiconductor equipment market is $40B, we are but a tiny percentage of that. Having worked in the semiconductor industry for the last 10 years, developing both plasma and laser process technology, I would like to express my opinion on why the take up has not occurred.

Incumbent Technology

In general lasers are marketed as an alternative to an existing technology and as such they have an uphill battle to gain market share. If we take wafer dicing as an example, the existing mechanical saws are cheap, reliable, fast, easy to use, and unfortunately in terms of the key metric of die strength, superior to laser cut wafers. Even though a laser has a lower depth of sidewall damage, studies consistently show the mechanically sawed dies come out on top. Although two-step processes exist to increase the die strength after laser dicing by removing the recast layer, it is an extra cost and is probably just as applicable to saw cut wafers, thereby negating its competitive advantage.

It is interesting to note that Disco, a leading provider of mechanical saw equipment, has performed best in terms of laser dicing equipment, with reports of around 40 machines installed in the last year. The reason may not be down to their technology as much as to Disco's closer geographical proximity to the majority of their customers and the fact that they have developed their products accordingly. Although the West still develops most laser technology, it is increasingly exported to the Far East. This separation of end user and product R&D centre generally diminishes uptake of any product.

Product Variation

Each semiconductor manufacturer has a different device, made up of different metals and dielectrics and varying in stack depth and die size. Even along the dice lane, the difference in alignment marks, test element groups and street width make the development of a generic laser dicing solution a hard task. The above is also applicable to through-silicon vias. In this case the ability to drill through the bond pad without destroying or delaminating adjacent electronic components is vital.

Additionally, since the majority of laser processes are backend, they are susceptible to changes in front end design. This means that an alteration to stack material in the front end could lead to a redevelopment of the laser process at the backend. One of the much touted killer applications for lasers was low-K scribing; however this never materialised, in part due to difficulties with the Low-K process itself but also that by the time the solutions were found the market had moved on. Although Low-K is still used, it will be 3-5 years before it becomes mainstream and even then it may remain a small percentage of the total number of wafer starts per year.

Laser Variation

In my experience the optimum laser parameters depend very much on the application and the material. For silicon machining, high pulse energy at 355nm seems the best way to go, presumably due to the correlation between the inter atomic bond strength of silicon, which at 3.5eV matches the photon energy of a 355nm laser. Although 532nm may have more power, nothing beats a resonant process in terms of efficiency and damage limitation. Is a 10 W picosecond system better than a 10 W nanosecond system? Apart from throughput, my own experience is that the picosecond system dumps a lot of energy in a very short time, which may have implications for sidewall damage and die strength. For other materials such as dielectrics and polymers, I think that low pulse energy, high rep rate is the way to go.

Most wafer damage is caused by rapid expansion of the material in front of the leading edge of the laser pulse train. This is especially true when you move from an area with metal in the dice lane to an area with dielectric e.g. test element groups in a dice lane. A high rep rate system tends to give the best results in these circumstances as well as producing the smoothest side walls. In an interesting talk at a recent AILU medical device seminar, Martin Sharp from the LLEC, showed that picosecond systems tend to have too much pulse energy; especially with regard to polymer ablation. It is also becoming apparent that the majority of sapphire scribing applications in Asia are using 1W nanosecond DPSS lasers. These are interesting results that should be taken on board by laser source developers.

Cost

Lasers in general are highly complex, with abilities such as pulse to pulse variation in energy and rep rate. I have never understood why such a level of over engineering is necessary in tools that will more than likely work within a very tight operational parameter range. The cost of this extra functionality is carried by the system integrator and must be passed on to the customer. This makes laser systems far too expensive for most applications. If you consider dicing, were the top end mechanical saws sell for $450k, if the comparable laser costs $150k before integration, margins are going to be very tight. Laser sources need to be cheaper. It is good to see low cost entrants such as the Laservall

Violino series and the SPI nanosecond pulsed lasers. I am sure that these lasers will find it easier to source applications within the market place.

A major concern going forward is who drives the development of laser sources? Why do I have to buy a laser source that can machine all dielctrics, semiconductors and plastics, when my customer is only interested in 200µm thick PTFE?

Many applications in both the medical and semiconductor sector cross my desk, and often the laser is the most efficient process. However, when you source the laser you find that it is not a cost efficient solution. More often than not it is a picosecond laser, with a €200k price tag, which puts the customer off. Newer companies, such as Fianium, seem to be taking this on board and are driving picosecond laser costs down; however there is still a way to go.

As a community with a common goal we need to work closer together to tie down laser specifications and hopefully lower laser unit costs. We need to look at new applications, were lasers are enabling and not up against incumbent technologies. However this may take a change of tack by the laser source developers. The existing approach, where the lasers are developed for existing markets such as wafer dicing, wafer scribing and silicon via production, just isn't working.

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PRESIDENT'S MESSAGE

It is my honour to be AILU President for 2008/2009. The outgoing President Clive Ireland put in a tremendous effort last year and it will be a hard act to follow. I know the rest of the steering committee is very appreciative of the work Clive did and I would like to thank him on their behalf.

One of the major initiatives that Clive introduced was the concept of sub-groups within steering committee. These sub-groups have specific topics to consider and take forward. Examples include AILU events, website and magazine, membership etc. The prime objective of these groups is twofold; improving the efficiency of the steering committee and reducing the secretary's workload. It is one of my goals to try to ensure the sub groups achieve these objectives.

Significant progress was also made by Clive in improving AILU's financial planning. This progress needs to continue as it is necessary for AILU to be on a sound financial footing with a positive cash flow each year. We will continue to strive to achieve this and any suggestions or input from the membership would be very welcome. Could I ask all members to spread the word about AILU and the benefits that it provides?

I recently attended an EU Innovation Forum which considered the future demands on laser processing in manufacturing and repairing aircraft, including aeroengines. Changes are occurring in the aircraft business including the use of new materials, expansion in breadth and depth of the supply chain and a move towards a more service based industry. These changes have affected the business drivers with more emphasis on reducing costs, especially whole life cycle costs. The implications for future laser processing systems are quite large and can be summarized as:

- Processes are needed that are applicable to new materials and combinations of materials
- Processes need to be developed that are
  ==> Robust
  ==> Portable
  ==> Devoid of black art
- Processes need to produce parts with high quality and reliability in order to minimise whole life-cycle costs.

Whilst these are challenging objectives I believe that there will be many new opportunities for laser processing in the future in the aerospace sector.

If anyone would like more information about this feel free to contact me through the AILU website forum or by email (s.williams@cranfield.ac.uk).

Stewart Williams