Contract Manufacturing with Added Value

It is a time of great opportunities in the micro technology world. Many developments in the machining, joining and replication fields have reached a high level of maturity and are now being implemented widely by companies developing new types of micro products.

▶ *Figure 1* ▶

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There has never been a wider range of manufacturing options available to micro technology innovators but accessing the right technology in this wide-ranging field is not always straightforward. Laser Micromachining Ltd (LML) is helping to solve this problem by combining multiple technologies under one roof, thereby allowing simple access to the right blend of technologies. This approach — a single facility for micro technology — enables new types of advanced micro-enabled products to be developed quickly and brought to market cost-effectively.

The micro technology landscape

The design, development, prototyping, manufacture and evaluation of complex micro products requires expertise and a set of skills which few companies possess. Unlike in the past when there were fewer manufacturing options, it is no longer practical nor economic for companies to retain in-house capabilities covering the myriad of different processes required in micro technology applications.

The pathway to take a product idea from concept to the consumer is usually a long and complex one and requires multiple issues to be solved: design ideas, material choices, machining options, packaging details, functional testing and manufacturing routes, to name but a few. Many of the initial ideas that are tried will not be suitable for any number of reasons but they have to be assessed anyway as part of a thorough development programme. The essence of making the concept-to-market pathway efficient and cost-effective is, therefore, to have ready, easy access to all the processes that are required and to be able to choose the most suitable technology for each stage of development; LML's micro fabrication facility offers this for a wide range of applications sectors using laser and other technologies.

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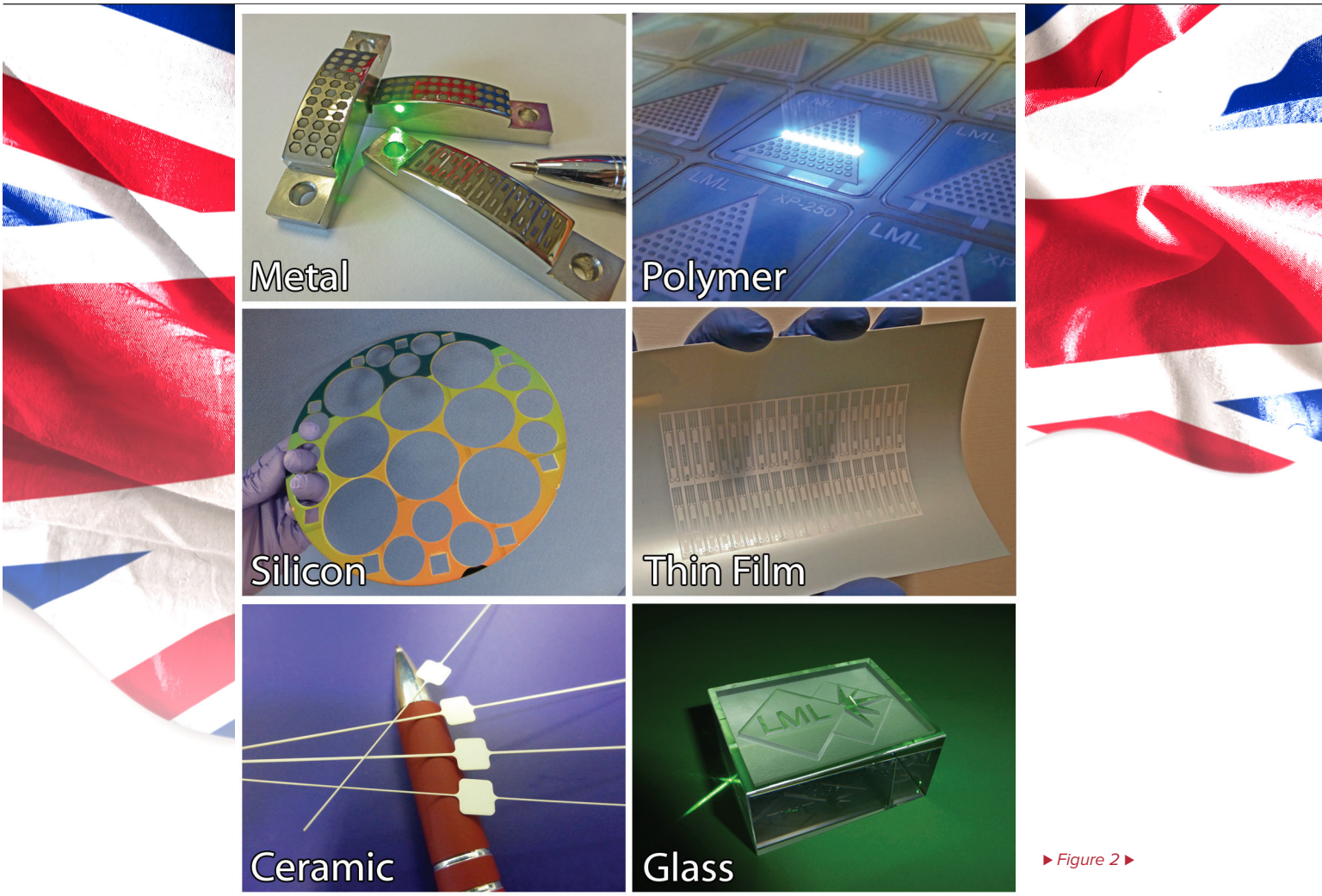

▶ *Figure 2* ▶

Trends in laser micro processing

Lasers are now an established, mature production tool and are used in the manufacture of all kinds of products, large and small. The biggest factors which make lasers the ideal tool for micro manufacturing are:

- *ability to machine any material*
- *high precision & fine resolution*
- *flexibility in features which can be produced*
- *non-contact, direct machining*
- *scalability from one-off to full production*

Obviously the above benefits rely not only on choosing the right laser but also in using it in the correct manner to achieve the desired results and LML has many years of expertise in developing highly-effective laser processing solutions. An example — shaped micro fluidic mixers machined in glass — is shown in figure 1.

The laser machining tools at LML comprise lasers with wavelengths from the UV to the near IR and pulse durations in the femtosecond, picosecond and nanosecond domains. This broad range of industrial lasers allows LML to utilise all the benefits of laser machining and produce high precision microfeatures in materials such as metals, polymers, glass, silicon, ceramics and thin films.

Based on customer requirements from more than a decade's worth of experience of supplying laser manufacturing services, there are two key aspects which stand out:

Scalability — a one-off good result is useless when it comes to developing a robust manufacturing route for a product so the laser facility has to be able to make small numbers of prototypes as well as being able to continue into larger-volume production with no loss of quality or repeatability. This requires a high level of sophistication in the laser tools and LML has invested heavily in ensuring that all its laser tools are able to be flexible for developments but are also rugged for production.

Flexibility — in a rapidly-evolving field such as micro technology, an effective machining facility has to be able to offer the best techniques using the latest lasers so that the widest range of requirements can be met. LML is committed to being the most versatile manufacturing facility for laser processing and has a continual improvement programme in place to have tools with the latest solid-state lasers, the most versatile ultrafast lasers and most efficient fibre lasers.

Lasers can cut, drill, mill, pattern and texture any material or combination of materials and some examples are shown in figure 2. In the majority of micro technology applications, structures in the range of about 10 microns to a few hundreds of microns in size are usually required and these features could be discreet ones (i.e. a single structure

in a device) or could be massively parallel in nature (e.g. millions of holes in a wafer); lasers can accomplish all of these requirements and do so in a highly automated and efficient manner.

Laser micro welding

In addition to removing material, lasers can also be used for welding materials together and LML has recently upgraded its facility to be able to offer micro welding of metals using fibre laser welding technology.

By appropriate use of a pulsed near-IR fibre laser, thin metals of many types can be welded together to give high-strength welds. Dissimilar and highly-reflective metals can also be welded with excellent, repeatable results and this is shown in figure 3.

Laser micro welding provides a number of benefits for the micro technology sector:

- *ability to produce in-situ micro welds on ultra-small parts*
- *minimal thermal input during welding, enabling sensitive parts to be welded*
- *high-strength welds*
- *ability to weld thin foils without distortion*

Laser micro welding using this IR fibre-laser technology is still relatively new and its mechanisms are still to be fully characterised but what is clear is that clean, strong, long-term welds can be produced for micro technology applications. LML now offers the precision laser machining of micro parts in conjunction with laser micro welding, a combination that will help more complex and multi-functional micro products to be produced.

3D printing

Undoubtedly the sector that has seen the biggest growth in interest in the past year is additive manufacturing. This is an all-encompassing term, which refers to the process of producing 3D parts by 'build-up' techniques rather than by subtractive methods like machining.

Additive manufacturing can produce parts by fusing, melting or layering materials, building up the design one layer at a time. To date plastics, metals, ceramics and glasses have all been used to make 3D parts and the list of compatible materials continues to grow. Despite the variety of methods, the most common implementation of additive manufacturing remains the melting of polymer wires to form parts and this process is usually referred to as 3D printing.

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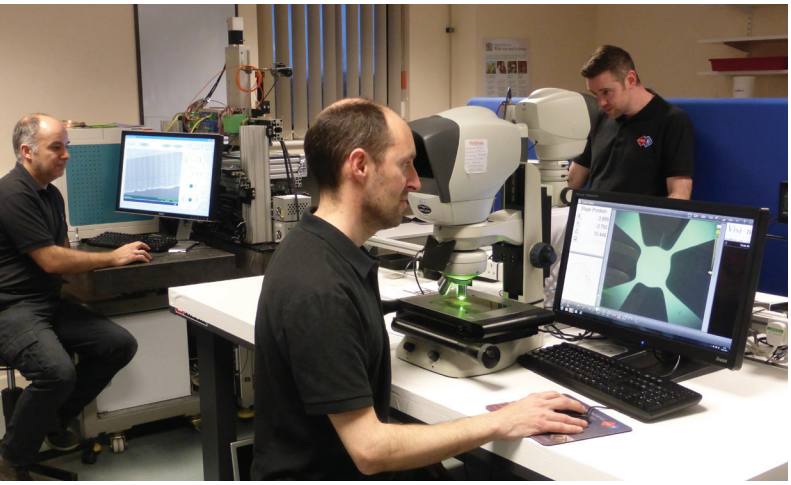
▶ *Figure 3* ▶

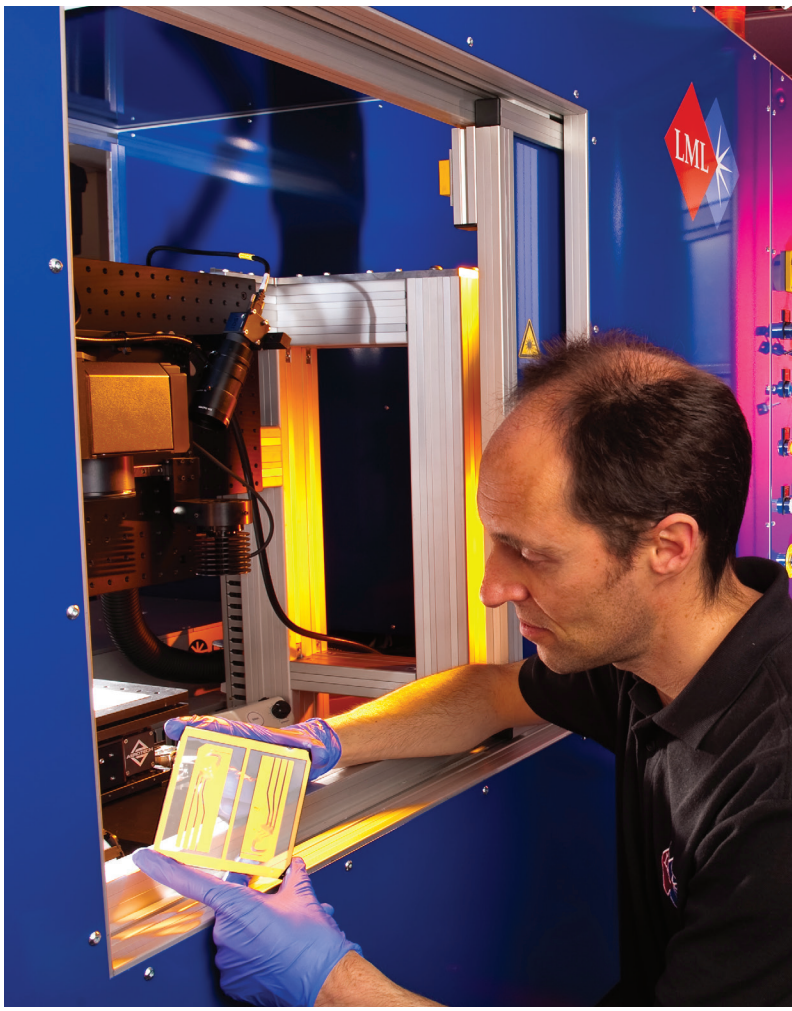
▶ *Figure 4* ▶

Packaging — 3D printing can also be used to produce housings or packaging for micro products. Whether this produces purely cosmetic/decorative holders or casings which are themselves functional as part of the product, the inherent flexibility of the 3D printing process allows novel designs of casings/housings to be achievable quickly for the first time. As micro products continue to be miniaturised, the interface to the outside macro world is becoming ever-more important. The ability to produce an integrated 3D design for the micro parts and their housings, and to be able to make them efficiently, is driving forward many new concepts.

LML has enhanced its manufacturing facility to add 3D printing capability (see figure 4) and hence a wider range of options is now available for users – depending on what the product designs require, LML can now not only produce parts by laser machining and welding but associated elements of the designs can also be 3D printed in a seamless manufacturing route.



▶ *Figure 5* ▶



Producing polymer parts by 3D printing is becoming more important in the development of micro products in two main ways:

Prototyping — small components can be 3D printed in a matter of hours as a means of evaluating a product idea. This offers an alternative to using injection moulding or hot embossing, both of which are relatively expensive for small runs and can also take a long time. Since modifying designs is trivial in 3D printing (unlike in other polymer replication methods when a new, expensive mould would be required), concepts can be easily and quickly tried out until a final design is achieved. It might be the case that another mass-volume replication method like injection moulding would be used in full production but the initial development can now be carried out relatively quickly and cheaply using 3D printing.

Measuring micro parts

It is an often-overlooked facet of micro manufacturing but thorough metrology of the parts that are produced is vital in developing a robust production route.

Due to the diverse nature of micro technology parts, a variety of complementary measurement techniques are needed to be able to measure the dimensions, surface roughness, repeatability and form of micro structures. LML has built-up a metrology suite which provides this capability (part of which is shown in figure 5).

LML has determined that it is crucial that customers who are having micro parts produced also receive comprehensive quantitative and qualitative measurements on the parts. This is done as a standard part of the manufacturing service and uses a combination of optical microscopy, scanning electron microscopy, optical sensor characterisation and optical imaging. LML's metrology facility possesses UKAS-accredited measurement equipment and so validated data can be supplied to the customer - this is an invaluable aid in the acceptance of micro parts produced by LML and gives the customer quantified data on the parts which are produced. In many cases the methodology of the metrology that is undertaken is agreed with the client so that the outputs can be properly integrated into the internal quality control procedures of the customer, further enhancing the manufacturing partnership.

▶ *Figure 6* ▶

Processing tools

There is a large element of skill involved in obtaining the best results from tools like laser machining or welding workstations but a lot of this skill can be transferred by proper design of the equipment, especially its user interface.

Many companies do wish to have some level of laser machining equipment in-house even if they don't wish to use it for full-time work. One of the main advantages of having some internal capability is that back-up development work can be done more freely (without the ideas leaving the company) and the tool can also be used to provide some back-up production capacity if required.

LML builds all of its own laser machining tools and so is highly experienced in the design, build and operation of advanced laser machining equipment.

The machining processes which LML develops for clients can be transferred to the client in one of LML's laser tools and this has been very successfully in recent years. The operation of LML tools is extremely simple and even non-expert users can operate the tools fully after a few days of training and practice — the secret lies in the user interface being intuitive, having recipe-driven operations for specific tasks and providing the user with the necessary process routines which they require. The other benefit of a company having the same equipment as LML does is that new processes that are developed at LML can then also be transferred easily to the user.

Laser processing tools are complex but they can be made to be user-friendly by proper appreciation of what the user requires and how they are going to operate it. LML provides R&D and manufacturing tools to customers on this basis and works closely with customers to ensure that the users obtain the best results from the equipment in a simple and efficient way.

Rapid and efficient product development

Production facilities like LML play a vital role in helping to bring complex micro products to market. As manufacturing options grow, with competing and complementary technologies, users can benefit from expert guidance on issues like design-for-manufacture and which methods to use to bring their designs to fruition. Facilities like LML bring together many of the required solutions in one place and are adding great value to the design-development-production pathway. ●

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