A

Seminar report

On

# Micromachining

Submitted in partial fulfillment of the requirement for the award of degree
of Mechanical

**SUBMITTED TO:**

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# Preface

I have made this report file on the topic **Micromachining**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to ……..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

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# Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

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# MICROMACHINING

Literally Micro in micro machining implies that parts are made to the size of 1 to 999 µm. However Micro also means very small in the fields of machining, manufacture of small parts are not easy. Therefore micro components should also indicate too small components to be machined Prof. Taniguchi defines Micro Engineering as the fields where components sizes are a few millimeters. When the part size is between 100µm to 100mm, a term MESO manufacturing is also used to address such parts. In fact, the range of micro varies according to era, person, and machining method, type of product or material.

## What is Micromachining?

Micromachining is the basic technology for fabrication of micro-components of size in the range of 1 to 500 micrometers. Their need arises from miniaturization of various devices in science and engineering, calling for ultra-precision manufacturing and micro-fabrication.

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# Why Micro Machining?

Why Micro Machining? Present day High-tech Industries, Design requirements are stringent. Extraordinary Properties of Materials (High Strength, High heat Resistant, High hardness, Corrosion resistant etc) Complex 3D Components (Turbine Blades) Miniature Features (filters for food processing and textile industries having few tens of microns as hole diameter and thousands in number) Nano level surface finish on Complex geometries (thousands of turbulated cooling holes in a turbine blade) Making and finishing of micro fluidic channels (in electrically conducting & non conducting materials, say glass, quartz, &ceramics).

## Application of micromachining

- Micro milling
- Micro grinding
- Chemical etching
- Micro punching
- Manufacturing of injection nozzles, Micro surgical tools, VLSI circuits

**Micromilling & MicroGrinding**

Among the conventional machine processes based on material removal from a workpiece, the most popular case those in which the useless part of the workpiece is removed by mechanical force through plastic or brittle breakage. In the process of this type, the first requirement of micromachining ,small Ur. Is satisfied when a high stress that causes breakage of material is applied to a very small areaor volume of the workpiece. Although cutting is the most conventional machining process, the availability of ultra precision cutting machines with highest level of positioning accuracy, has enabled us to apply this process in micromachining.. Turning, milling and griding are examples of processes of this type. For realising this a tool that was its edge sharpe

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Micromilling & Microdrilling is capable of the fabricating holes several tens of micrometers in size for practical applications other types of products such as grooves, cavities and 3D convex shapes may be fabricated when a micro end mill is used instead of a micromill. In such cases, the machining force exerts a larger influence on accuracy because the main direction of the force is perpendicular to the tool axis.

Microgrinding can be applied to the fabrication of micropins and microgrooves, where a grinding wheel with large diameter can be used for such application. The only requirement is to reduce the thickness of the grinding wheel to the required resolution of the product, for example, the width of the grove. The thickness of tens of micrometer order is available so far and correspondingly narrow grooves are reasonable targets of this method. Submicron – order grains of diamond, tungsten carbide or CBN are desirable for realizing good product geometry. The UR of grinding is small because cutting is realized by means of micrograins. However, in the field of micromaching, it is not always a superior method. One of the technological problems is the fact that the tool must be made up of an abrasive and a matrix .when the tool size is very small, the grain size cannot be ignored; this leads to certain difficulties in forming the precise shape of the grinding wheel.

**Chemical etching**

Chemical or electrochemical dissolution in liquid is also utilized in micromachining. In this type of process, the removal mechanism is based on ionic reaction on the workpiece surface. This leads to very small UR in the direction perpendicular to the surface. The other two dimensions are usually specified by a patterned mask. The advantages in etching besides a small UR are as follows:

- The machining force is almost zero
- The surface after machining is free from any damage, residual stress or heat effects
- The mechanical properties of the workpiece do not influence the removal mechanism
- In most cases the dissolution phenomenon renders the workpiece surface smooth.

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Chemical etching is the process of removing layers of silicon in the atomic dimensional level through chemical reaction between a chemical etchant solution and the exposed silicon surfaces. The bonds between the atoms on the surface and the ones immediately underneath are broken in the process and the surface atoms come out loose. If the etching proceeds predominantly in one direction while the etching does not proceed in the perpendicular direction, then it is called as anisotropic etching. In contrast, if is called isotropic etching. The following are the two types of etching predominantly used.

**Punching (plastic Deformation)**

As there is neither removal nor addition of material in these processes , UR is meaningless. In order to introduce this method into micromachining, we must be able to manufacture the micropounch and die can be produced by applying appropriate micromachining technologies explained above. Therefore, the realisation of micropouncing depends on the development of a system that ensure easy setting of microtools.

The most remarkable advantage is the production speed in many cases, the machining time is of millisecond order in principle. This indicates the suitability of these processes for mass production . the main issue ----- loss of accuracy is the spring back phenomenon or the partial recovery from deformation after processing. Another issue is the flowability limit of the workpiece material. The flowability is sometimes insufficient to follow the sharp corners of the die/mold . the basic restriction of these processes is that only workpieces softer than the die/mold can be processed.

**Micromachining conditions**

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The machining processes for micro/meso manufacturing can be derived from traditional machining processes such as turning milling, drilling, grinding, EDM, laser machining, etc., by judicious modification of these machines. Unit metal removal and improving equipment precision are the key factors for adapting the traditional machining processes to micro machining. When these two guidelines are set, the approach is almost correctly directed toward micromachining.

**Unit removal**

The concept of unit removal was introduced as processing unit by N Taniguchi to explain the difference in removal phenomena between micromachining and conventional machining. Unit removal (UR) is defined as the part of work piece (length, area or volume) removed in one cycle of metal removal operation. Since UR gives the achievable tolerance on the part it should be much smaller than the size of the part it should be much smaller than the size of the component. The smallest UR is the size o0f the atom. UR of sub-micrometer order is also required when the object size is very small or when high precision of the product is required. It is difficult to achieve ideal UR and machine accuracy in the lower range of sizes, say 1 to 10 microns

**Equipment precision**

When a maniaturised part is required the component is scaled down. Then, it is necessary that the dimensional error of the product be likewise reduced. Therefore, higher precision of the micromachining equipment is desired although it is often impossible to reduce the dimensional error in proportion to the size of product. If the above two equipments small UR and high equipment precision were satisfied micro-machining would be possible independent of

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the type of machining process. Since the theoretical minimum UR possible in mostprocess are of of the nanometer order. Micro-machining is thoreitically possible in most existing machining progresses on the other hand the theoretical smallest UR is largest than the size of the atom. This suggest that in micromachining in the lower range of dimensions for example. 1 to 10 µm it mavoe more difficult to achieve the ideal UR and equipment precision because of the influence of this absolute limit.

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# Classification according to machining phenomena

- Removal by Mechanical Force
- Removal by ablation
- Removal by dissolution
- Plastic Deformation

The following Table shows the major methods grounded by the machining mechanism and the work material amenable for those process.

Table: Micromachining Processes

| **Machining phenomena** | **Micromachining Process** | **Materials** |
|---|---|---|
| Force | Micromilling , micro grinding | Ceramics, metals,si |
| Ablation | Excimer Laser, Femto Second Laser | Ceramics, Polymers |
| Dissolution | Etching, ECM<br>Reactive ion etching (R:E) | Galss, Quartz Si<br>Ceramics, Polymers |
| Plastic Deformation. | Punching , Press | Plastic Deformation |

**LASER MICROMACHINING**

unlike the $CO_2$ or Nd: YAG lasers, Examier and Femto Second lasers, on the contrary, offer high-precision machining without the formation of a re-solidified layer and a heart –affected zone. There are two types of methods that are based on material removal by ablation. One uses a power source that emits a beam with very high quantum energy. If the energy exceeds the binding energy among atoms of the workpiece each molecule can be decomposed directly into atoms and removed from the workpiece. The other method uses an energy beam of which incident power density on the workpiece is extremely high such a high power enables the removal of the workpiece by vaporization, skipping the phase of melting in some cases, molecules are also decomposed in both types, microshapes can be generated by projecting mask patterns, whose size is reduced by using optics. Excimer laser and femto second lasers (hereafter referred to as FS lasers) are respectively typical examples of power sources for the above two types. The Excimer laser is

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an ultraviolet laser which can be used to micromachine a number of materials without heating them, unlike many other lasers which remove materials without heating them, unlike many other lasers which remove materials without heating them, unlike many other lasers which remove material by burning or vaporising it. Higher accuracy can e achieved when a shorter wavelength, for example, 193nm of an ArF laser is applied. Since the applied photon energy is similar to the energy level of molecular bonds in plastics, the ideal targets for excimer laser machining are plastics, and similar materials and not metals. When a very high power is applied, the removal phenomenon involves a combination of heating and photon attack. FS lasers have short (femto second) pulse duration and high (tera watt) power and overcomes the above limitation. The remarkable feature of these methods is that little heat affected layer remains on the machined surface. This leads to the possibility of machining microshapes with high dimensional accuracy and less defects in the surface layer. The main drawbacks are low efficiency in material removal and consequently, low machining speed another drawback is the high cost of equipment due to their short history.

**SETUP**

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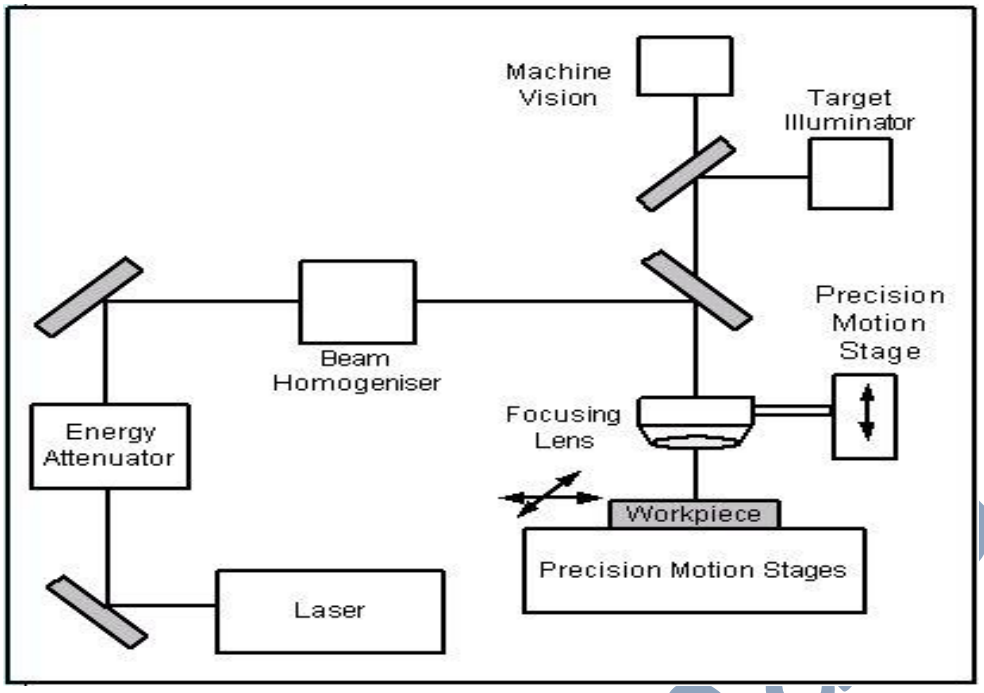


**Conceptual Solid Model of Laser Micromachining Setup**

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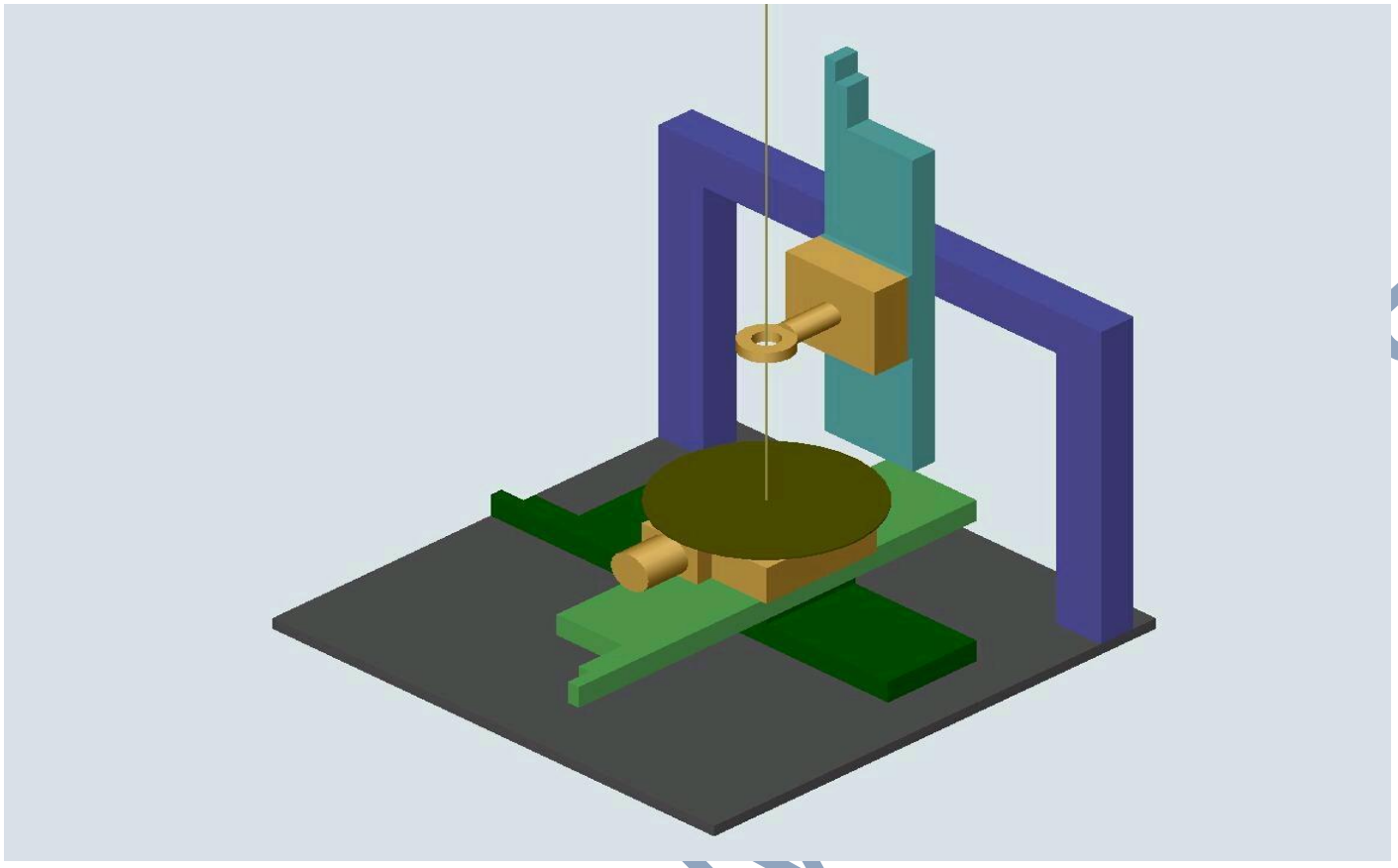

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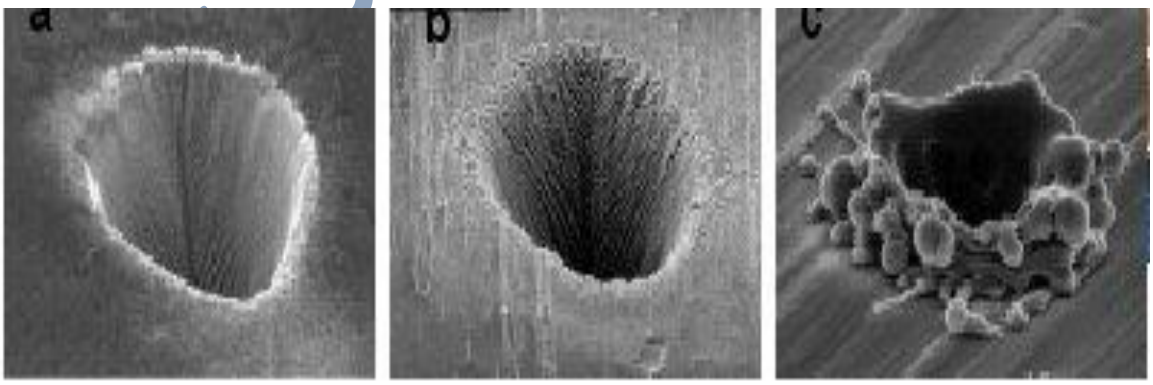
# WORKING

Laser is emitted from the source is passed through the energy attenuator. After it is passed through the beam homogenizer to homogenize the beam. The target illuminator and machine vision controls the beam to the focusing lens. The lens is moved by precision motion stages. The beam is then falls on the work piece and the machining is takes place.

**Characteristics of Femtosecond Laser Micromachining**

- Very high peak powers in the range 1013W/cm2 provide for minimal thermal damage to surroundings
- Very clean cuts with high aspect ratios
- Sub-micron feature resolution
- Minimal redeposition
- Possible to machine transparent materials like glass, sapphire etc

**Ultra short Pulses vs. Long Pulse Micromachining**

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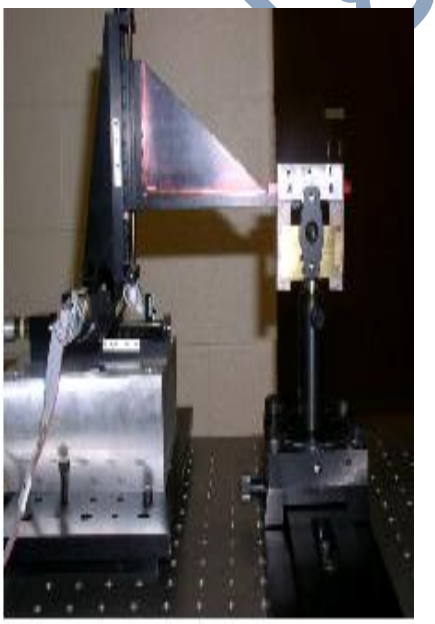
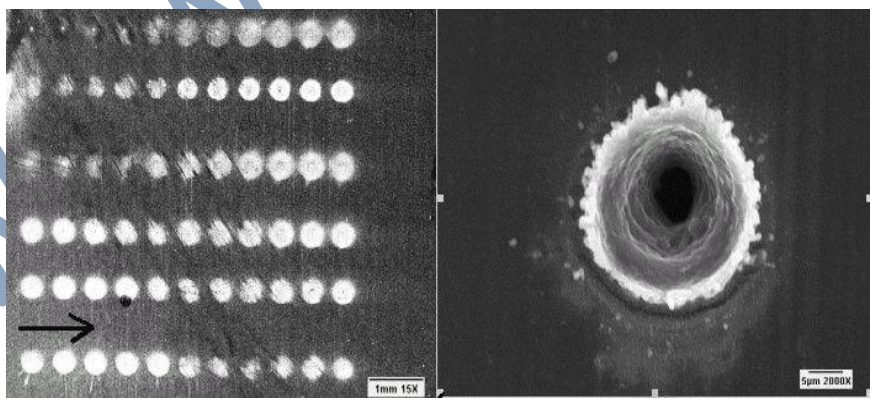
**Femtosecond Laser Micromachining**



**Micromachining in 18µm Thick Aluminum Foil**

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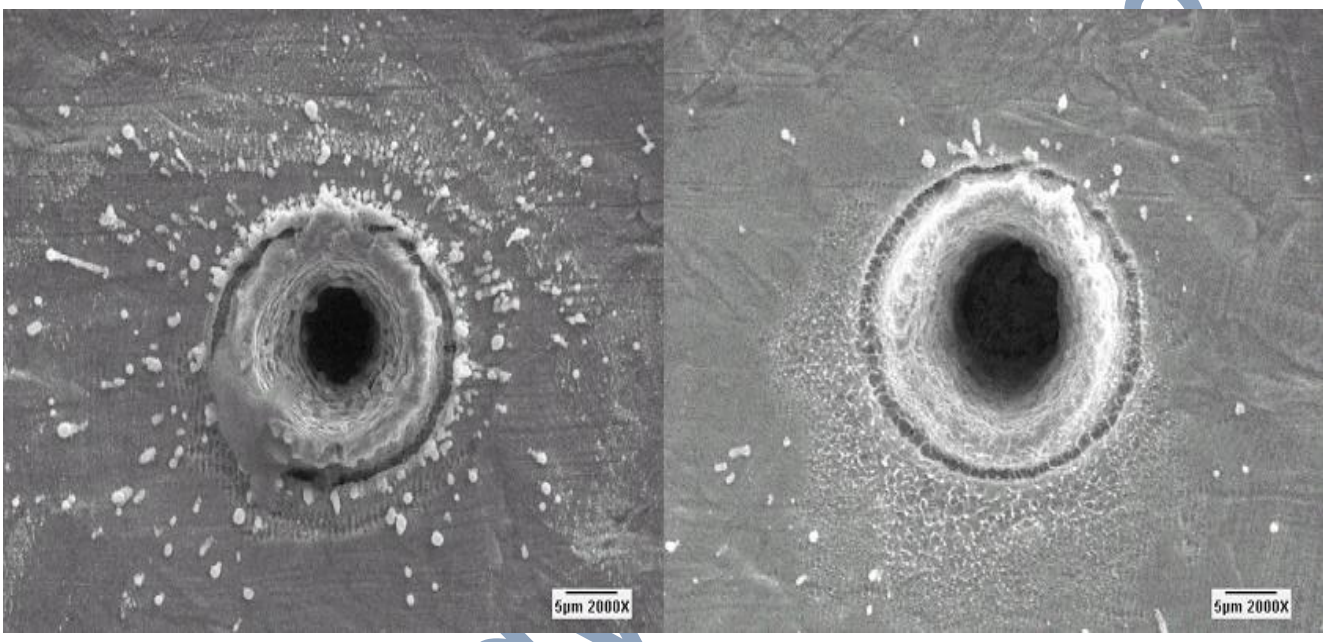
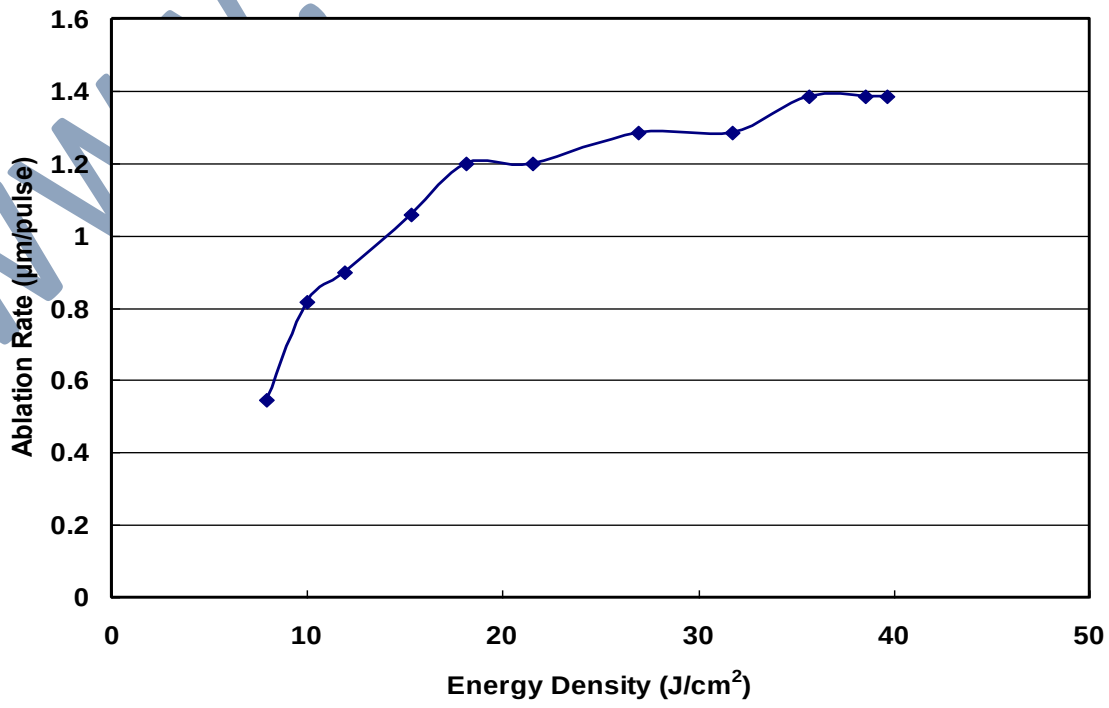
**Holes drilled in 25µm thick brass foil**




**Ablation Rate vs. Energy Density in 18µm Thick Aluminum Foil**

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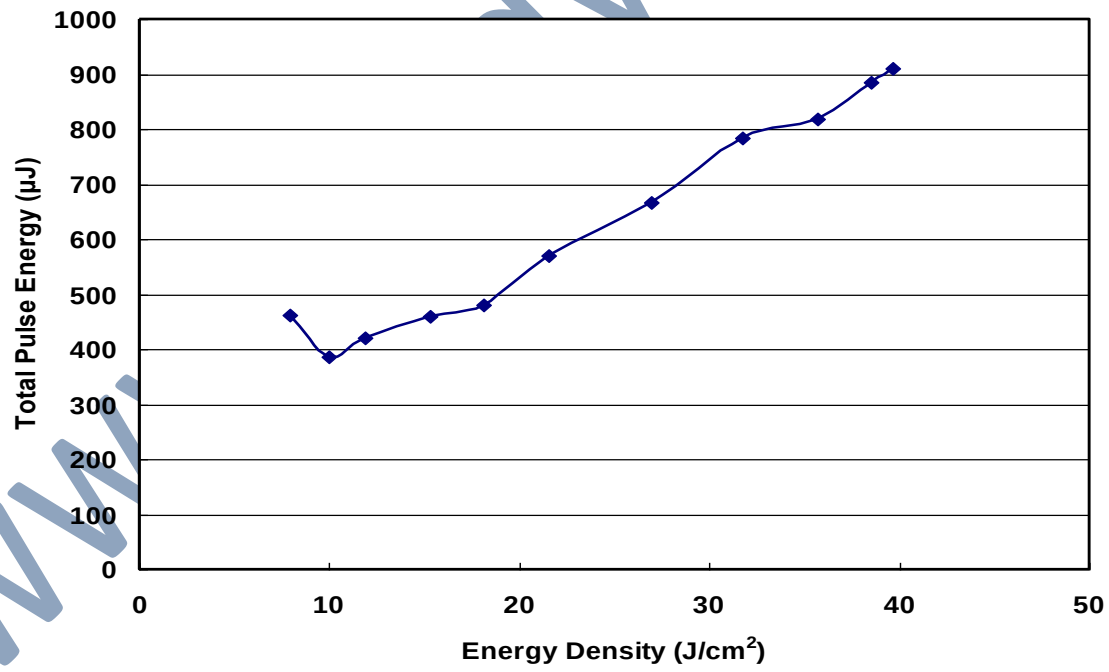
**Optimization of Pulse Energy Required to Drill Holes**

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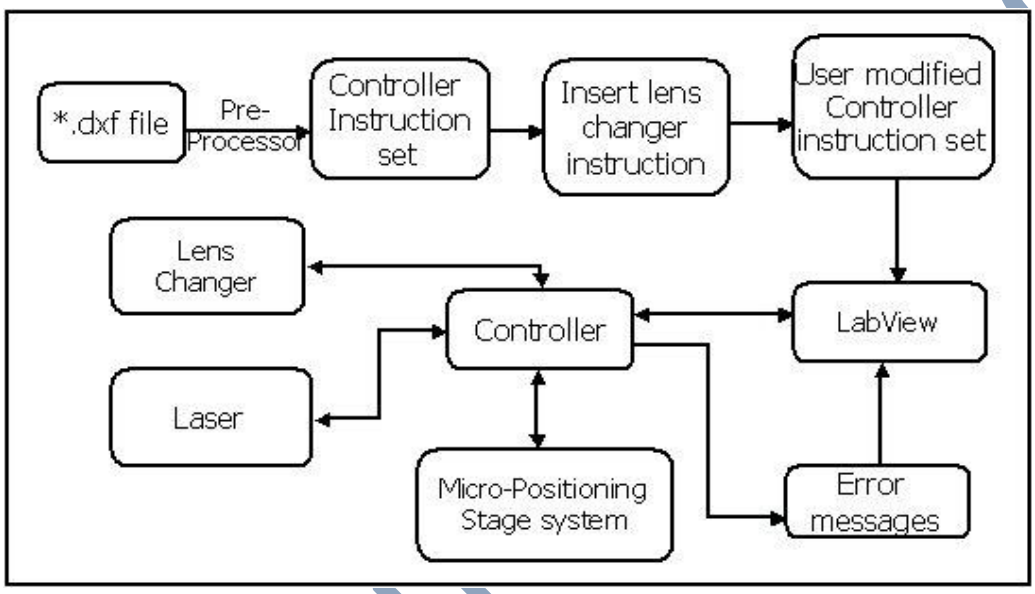
**Automation of Laser Micromachining Process**




**Advantages of Laser Micromachining**

- Non-contact machining
- Very high resolution, repeatability and aspect ratios
- Localized heating, minimal redeposition
- No pre/post processing of material
- Wide range of materials: fragile, ultra-thin and highly reflective surfaces
- Process can be fully automated

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## Conclusion

Technology and 'request to technology' influence each other. As a result, the front of technology advances as the front of request to technology moves to a higher level. As regards micromachining the dimensions of the product is one of the good indicator of the levels of technology and request. However, he level of request from the industry varies widely. The development of technology owes much to the high end of the request. Consequently, the average level of the request is always behind the front of technology.

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