Laser Assisted Mechanical Micromachining

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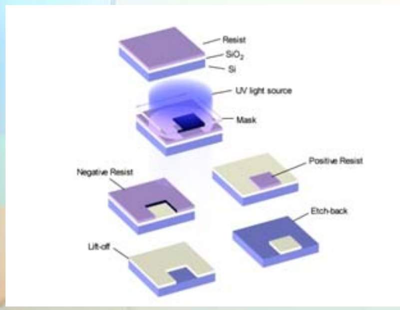
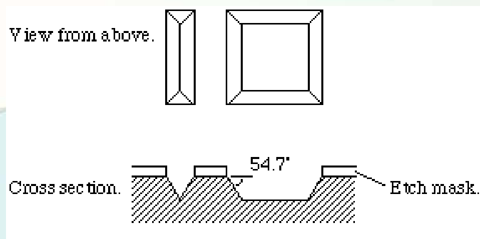
IAB Presentation
PMRC, MARC

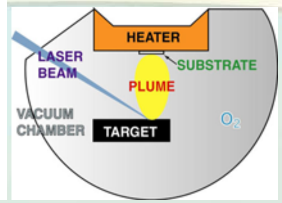
Conventional Micromachining Vs. Mechanical Micromachining

Conventional Microstructuring

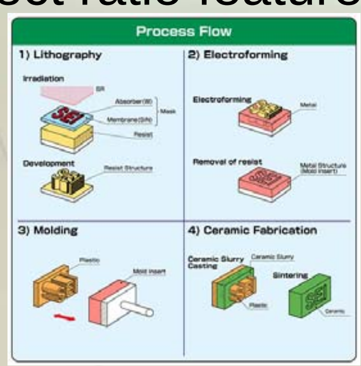
- Silicon-based & low aspect ratio features
  - Optical/X-ray Lithography [1]
  - Etching
  - Laser Ablation [2]





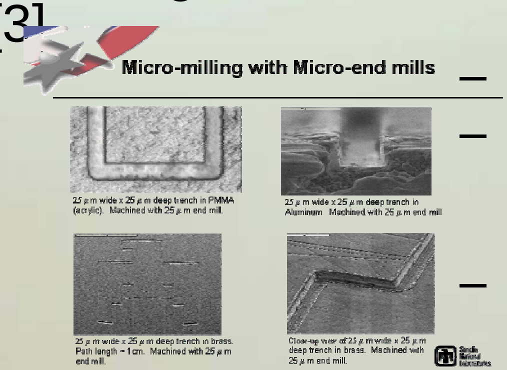


- Versatile (metal and polymers) and high aspect ratio features by LIGA [3]



Mechanical Micromachining

- Advantages over conventional methods
  - Variety of materials can be processed
  - High aspect ratios can be achieved
  - No use of clean room
  - No synchrotron radiation machine required for X-ray
  - No sacrificial layer
  - Complex 3-D surfaces can be realized
  - Economical



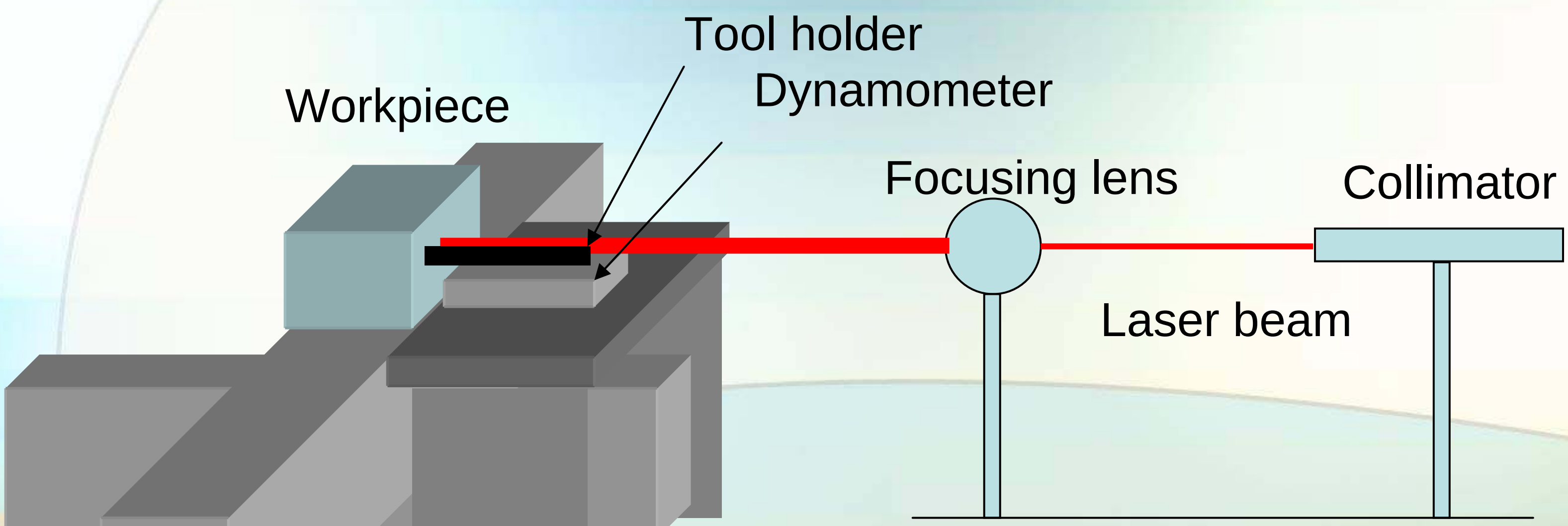
Laser Assisted Mechanical Micromachining (LAMM)

- Motivation
  - Miniature cutting tools lack adequate stiffness and strength for micromachining of hardened tool/die steels
  - Laser assisted mechanical micromachining has not been studied at micro/meso scales
  - Processing of wide array of materials can be explored

Proposed Research Issues

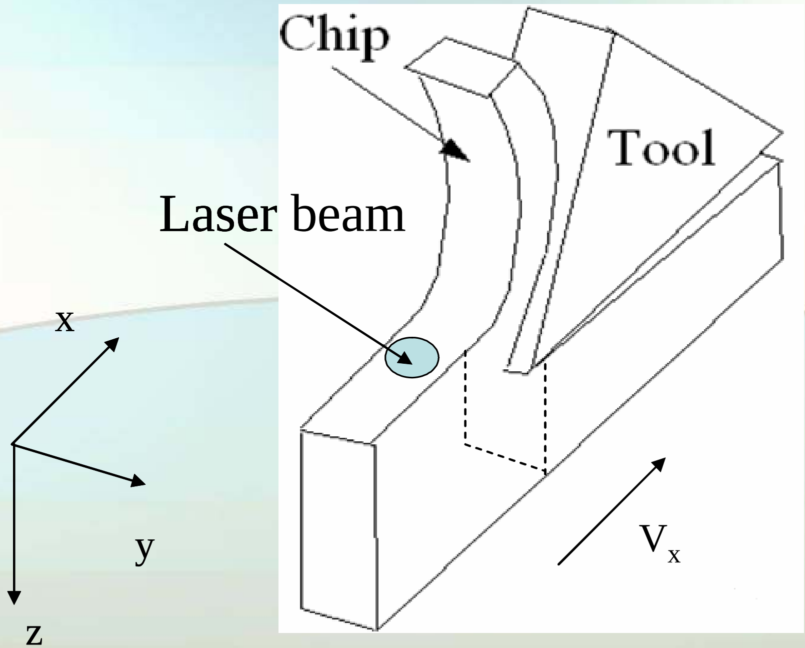
- Initial feasibility studies
  - Fabrication of LAMM setup
  - Design 2-D cutting experiments to conduct a parametric study of the effect of spot size and intensity on cutting force and surface integrity
- Process characterization and modeling
  - Tool wear
  - Surface texture and microstructure integrity
  - Thermal modeling
  - Cutting force prediction
- Process optimization
  - Tool wear
  - Heat affected zone
  - Surface quality and subsurface damage

Experimental Setup



General arrangement of LAMM Setup

Laser Assisted Mechanical Micromachining (LAMM)
Thermal Modeling Approach



Solve the energy equation for moving heat surface

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+\dot{q}=\rho c_p\frac{\partial T}{\partial t}+\rho c_p\frac{\partial V_x}{\partial x}$$

Laser Assisted Mechanical Micromachining (LAMM)

Oxley's model for cutting forces

Johnson Cook's equation for flow stress would be used for Oxley's model

$$\sigma = \left(A + B\varepsilon^{n}\right)\left(1 + C\ln\frac{\dot{\varepsilon}}{\dot{\varepsilon}_{o}}\right)\left[1 - (T^{*})^{m}\right]$$

where $$T^{*} = \frac{T - T_{r}}{T_{m} - T_{r}}$$

Input cutting parameters

The value of T_r would be calculated from the thermal model

Other Investigation Issues

- Microstructural integrity of heat affected zone
  - Apply models used in welding literature
- Tool Wear
  - Optimize input parameters to reduce tool wear
- Surface integrity
  - Investigate surface finish, subsurface damage and residual stresses

Summary

- Process characterization and optimization of LAMM
- Provide empirical and scientific basis for production-grade LAMM
- Augment mechanical micromachining technique
- Novel applications such as nanocrystalline metals and ceramic processing can be studied