Measurement of micro-displacement based on the localized interference scale formed by standing wave
The Outline of This Presentation

[1] Introduction: Background & Purpose
[2] Principle of measurement
[3] Experimental approach
[4] Conclusions
1. Introduction: Background & Purpose

2. Principle of measurement

3. Experimental approach

4. Conclusions
Introduction: Background & Purpose

Recently, the micro-system has been developed

- Steep surface
- High aspect structure
- Edge
- Groove
- Hole

Dimensional measurement for micro-components

- Confocal microscope
- Profilometer
- White light interferometer
- Auto-focus microscopy (SPM)
- Scanning probe microscopy (SPM)
- Scanning electron microscopy (SEM)
- Micro-Coordinate measuring machine (Micro-CMM)
Objective

to develop measurement technique for micro-components especially applicable to MEMS components also.

Propose new scanning type dimensional measurement method by using the optical trapping technique and the interferometric pattern

In this presentation, the principle of measurement is described fundamental properties are experimentally
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Optical trapping technique

is to trap microscopic object 3-dimensionally by using a focused laser

**Principle of optical trapping**

- Tightly focused laser beam is incident to the object to be trapped
- Upward-directed optical radiation pressure force is generated, when laser refracts on the surface

**CCD image**

- Trapped sphere (Φ8μm)
- Silicon wafer

Probe sphere is pull into the laser spot
Optical trapping technique

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**CCD image**

Trapped sphere (Φ8μm)

Silicon wafer

NA0.80, WD=3.4 mm
A standing wave is generated along with the optical axis by interference between the trapping laser and a retro-reflected light. 

Localized interference pattern
Localized interference scale

$(\lambda = 1064\text{nm})$

Laser

Probesphere

Incident light

Z-axis

Surface

Standing wave as localized interference scale

Reflect light


• Intensity distribution of standing wave on the optical axis

$$I(z) = I_0\left[1 + \alpha \cos\left( \frac{4\pi z}{\lambda} \right) \right]$$

$\lambda$ : Wavelength  \hspace{5pt} z : Displacement along z-axis

• Pitch of localized interference scale

$$z_{\text{pitch}} = \frac{1}{2} \lambda$$
• The probe sphere is moved regularly by radiation pressure force generated by standing wave.

• The localized interference scale is read by regular displacement of the probe sphere.
The localized interference scale moves up with displacement of the surface in the $z$-direction.

Displacement of the surface $z_{\text{pitch}} = \lambda/2$ can be detected by jumping of the probe.
Form measurement by probe scan

- The probe scan above the object to be measured

- Surface displacement measurement using the localized interference scale
Form measurement by probe scan

- The probe scan above the object to be measured

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**Measurement accuracy**

**Experiment**

- Probe approaches toward surface at constant speed (1.4 µm/sec)
- Traveling distance is 100 µm
- Silicon wafer (1 nm Ra) is employed as surface

**Result**

Glass microsphere (8 µm) is trapped

- Detected signal
  - saw tooth shape wave signal
- Detected pitch of standing wave
  - Mean: 534 nm
  - ± 30 nm
Measurement range

Experiment

Getting away

Probe

Working distance

Surface

Probe gets away from surface at constant speed of 1.4 $\mu$m/sec

Measurable range is determined if the saw tooth shape is recognized from raw data of signal

Result

Surface displacement from 15 to 250 $\mu$m is measurable.
3D form measurement

Experiment

Probe scans 10 µm above top of micro-lens at constant speed of 1.4 µm/sec

As workpiece, micro-lens (r= 3 mm) is used

Measured data is compared with data of confocal microscope

Measured data

Localized interference scale sensor

Probe

Single scan

Glass microlens

Experiment

Glass microlens

Probe

Single scan

Localized interference scale sensor

As workpiece, micro-lens (r= 3 mm) is used

Measured data is compared with data of confocal microscope

Measured data

Probe scans 10 µm above top of micro-lens at constant speed of 1.4 µm/sec
3D form measurement

Difference

Measured data

Localized interference scale sensor

Confocal microscope
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Conclusion and future work

- New method for dimensional measurement using an optically trapped probe and standing wave is proposed.
- The method is theoretically and experimentally confirmed.

Future work

- The potentiality as a measurement sensor of a narrow concave with high aspect ratio will be investigated.

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METI: Ministry of Economy, Trade