Ref: A (not so) short introduction to MEMS jb
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Characterization: MEMS Date: 26/02/2015

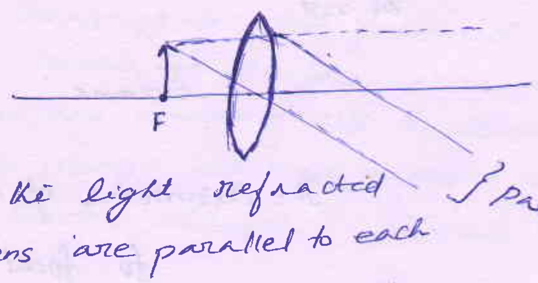
- Small dimensions of the MEMS devices makes it hard to properly measure their geometries or observe their operation by simply using rulers or naked eyes.
- Here, we will discuss a few of the important tools used.

(1). Light Microscope:

- used at the end of each process steps for quality control or after fabrication to see the functioning of the device.
- Most used microscope is the reflected light infinity corrected compound microscope.
  * Compound → it uses two sets of lenses for magnifying the sample.

    Here a real magnified image produced by one lens (or lens system) called the objective is further magnified by another, the eye piece, which forms a final, magnified virtual image for observation by the user.
  * Reflected → the optical path for observation and illumination are from the top allowing opaque sample observation.
  * ~~Light~~ Infinity corrected: →

    Here the object is placed at the focal plane of the objective lens. i.e



Hence the light refracted from the lens are parallel to each other or we can say the image is formed at infinity. } parallel lines

- Use an additional lens (the tube lens) placed after the objective to form in its focal plane (f_T') the real image of the object

- Finally the eye piece focal plane is positioned at the intermediate image plane for forming an image at infinity (eye).

<u>Magnification</u>: - parameter describing the apparent enlargement of the object when observed through a microscope.

$M = M_0 M_E$, M_0 - objective $= f_T / f_0$

M_E - Eyepiece $= \frac{250 mm}{f_E}$

$M = \frac{f_T}{f_0} \frac{250 \times 10^{-3}}{f_E}$; f_T : focal length of tube lens

f_0 : focal length of objective

f_E : focal length of eyepiece

<u>Resolution</u>: resolving power of the microscope and gives the shortest distance between two points that can be resolved.

- mostly due to diffraction effect.

- The image of a point object observed by the objective and formed by the tube lens in an infinitely corrected microscope is not a point, but an Airy disk.

- The criteria for resolution is whether the Airy disk produced by two neighbouring points can be distinguished or not.

$$\delta x_{min} = 1.22 \lambda \frac{f_0}{D},$$

D = diameter of the objective entrance pupil,

f_0 : focal length.

<u>Depth of field</u>: The depth of field gives an estimate of how much offset can be tolerated before the image is too blurred.

Numerical Aperture: → light gathering power of the objective.
numerical aperture is defined as

$$NA = n \sin \alpha.$$

n - refractive index of the medium at the lens entrance.

α - the incidence angle of the most extreme ray that will be accepted by the lens.

2). Scanning Electron Microscope:

- resolution up to 1nm.
- allows finding material composition or morphology.
- Vacuumed instrument column where primary electrons are produced, accelerated and shaped in a beam before they are focused and scanned on the surface of the sample.
- At the impinging point, the interaction between primary electrons and the sample results in the generation of different signals that are measured with multiple detectors.

Secondary Electron Imaging :→ Secondary electrons that are produced near the surface (<50nm). of the sample where impinging electron are able to free electrons from atomic shell. without them being re captured.
The number of electrons generated depends on the topography.

Back scattered electron Imaging → are produced in a larger volume (1-2μm) below the surface when the primary electrons recoil as they interact with the atoms. In this case the no. of electrons returned depends on the atomic number of the element. Larger Z number brighter image.

X-ray spectroscopy → X-rays are produced when a vacancy appear in the inner shell of the atoms are filled. and the most common technique is the energy dispersive X-ray spectroscopy (EDS) ...

sample for elements between known and unknown.

(3). Contact probe profilometry

→ Details discussed in class.

and sometimes quantitatively the atoms present in the sample for elements between Boron and Uranium.

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