EVANESCENT FIELD OPTICAL MICROSCOPY

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Optical microscopy has attained a high degree of perfection in its confocal form. However as modern technology is evolving from micrometre to nanometre size structures the lateral resolution limited by diffraction to $\sim \lambda/2$ is becoming a drawback. Yet a light wave diffracted by a sample does display information on a subwavelength scale, but these waves cannot propagate, they evanesce and are confined to the so called near field. For a long time evanescent waves were not considered as of practical importance to microscopy, but the invention of the scanning tunneling microscope has stimulated a fresh approach towards the practical exploitation of the optical near field.

Pioneering experimental studies, started around 1984, of near field interaction from a nanometre-size aperture demonstrated a lateral resolution of $\lambda/20$ (1). The Evanescent Field Optical Microscope (EFOM) is an alternative set-up which employs frustrated total internal reflection on a highly localised scale by means of a sharp dielectric tip. The principle, often referred to as Photon Scanning Tunneling Microscope (PSTM) has been reported by several groups (2,3,4) since 1989.

The experimental set-up of the EFOM is sketched in Fig. 1. The evanescent field is generated by total internal reflection of a laser beam in a glass substrate. A sample placed on the glass substrate together with an immersion liquid causes a spatial variation of the evanescent field which is characteristic for the dielectric and topographic properties of the sample. The field is frustrated and converted into a propagating wave by a suitably sharpened dielectric probe, which consists either of a quartz fibre sharpened to about 100nm tip radius by chemical etching, or of a diamond tip (Drukker Diamonds, apex $\sim$50nm radius) glued onto the facet of a cleaved quartz fibre. The optical power (0.1-1 nW) coupled into the fibres is detected with a photo multiplier tube. An image is obtained very similar to the STM by manipulating the optical probe tip with nanometre precision in lateral and vertical directions over the sample surface by means of a piezo-electric scanner (Microblock, Photon Control). During a scan the optical signal is kept constant by a feedback system which acts on the piezo-electric element in the vertical direction, "the optical tunneling mode".

Fig. 2 shows the EFOM image of a 4×4μm scan of a photoresist grating, fabricated by standard masking and etching techniques, with 500nm steps and 100nm height variation, illuminated with a p-polarised HeNe laser beam incident at 0.24° from the critical angle for total internal reflection. To demonstrate the resolution capacity of the EFOM latex spheres with dimensions smaller than the optical wavelength were scanned. An EFOM image of a 2×2μm area with closely packed spheres of 481nm diameter is displayed in Fig. 3. The spheres can be clearly distinguished. Vertical height variations extend over 180nm.

The results demonstrate the capacity of the EFOM to circumvent the diffraction limit and obtain sub-wavelength resolution. The lateral resolution of $\sim$100nm is determined not only by the sharpness of the probe tip but also by the exponential decay of the evanescent field itself, which can be controlled by choosing angle of incidence, working distance and wavelength.

Near field Optical Microscopy applies to all techniques of conventional optical microscopy, e.g. detection of luminescence and polarisation effects and use of phase information, with a resolution approaching that of an SEM. This is a major improvement for optical spectroscopic applications. The microscope operates on dielectric surfaces in contrast to electron microscopy (SEM, STM) which is restricted to information associated with electrons and operates only on conductive surfaces under vacuum conditions.

The technique, presently still in the development stage and only demonstrated on test samples, is highly promising for application to chemical samples (polymer films, Langmuir Blodgett layers), biological samples (lipid films, filamental proteins, membranes, chromosomes, labelled by fluorophores or immunogold techniques) and technical surfaces (optical thin films, photoresist structures, IC masks).

References

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Fig. 3: 2×2μm EFOM image of ϕ481nm latex spheres.

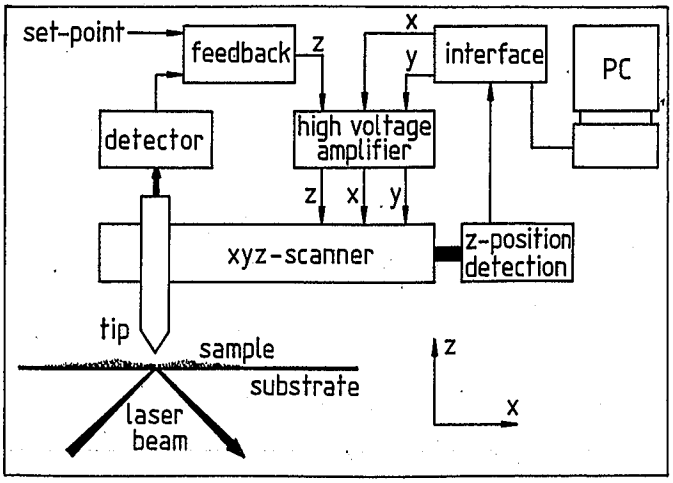

Fig. 1: Schematic set-up of the evanescent field optical microscope.

Fig. 2: 4×4μm EFOM image of a 500nm step photoresist grating.