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APPLICATIONS OF MICROLENSES ARRAYS

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ABSTRACT: This paper has presented some applications for microlenses such as: fiber coupling and optical switching, collimation of lasers diodes, imaging systems and sensors, beam homogenizers for lasers und illumination systems, array optics featuring high precision, aspherical lenses for creating the best imaging characteristics, etc. In generals, microlenses have a diameter between 10μm–5mm and a curvature radius of 0.25—2.5mm. A real problem is controlling radius of curvature which must be more uniform.

1. INTRODUCTION

In last years the using of microlenses is taken a large and versatile application. Microlenses [3,4,6] are discrete or array based spheres, aspheres and other optics being used for focusing light inside fibers for optical networking or vision system. In generals, microlenses have a diameter between 10μm–5mm and a curvature radius of 0.25—2.5mm. A real problem is controlling radius of curvature (ROC) which must to be uniform for a performing focus light on fiber and reduce signal loss.

Widely, microlenses array are created by etching or molding glass, silicon or plastics substrates (fig.1). The variation of ROC lenses in across substrate can be critical going to uneven resist thickness or changes in reactive ion beam etching process, substrate failure can be appeared at ROC tolerances held to less 10μm [4].

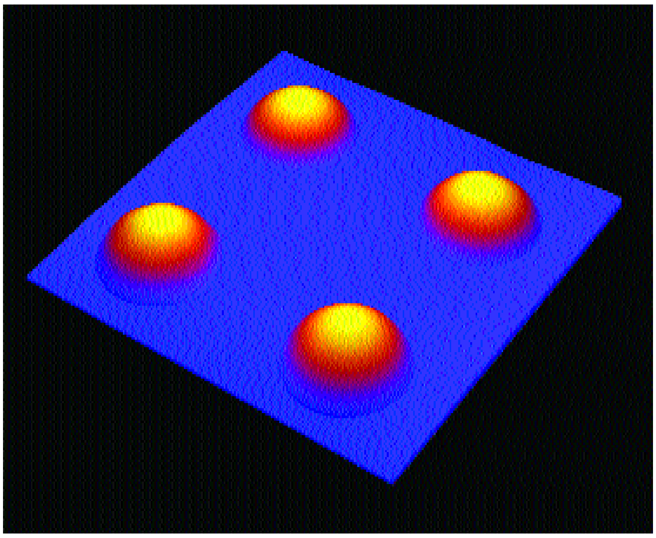


Fig.1. Microlenses array with height of 20μm.

So, in this case the problem of ROC measurement became very important. Ones well-known measuring method is Optical Profiling (White Light Interferometry) [4], which using a non-contact technique, 3D surface roughness and shape measurement of microlenses and other optical components.

Optical profiling method assured an accuracy measurement, for ROC measurement with an error less than 1%, and less than 0.5% error on larger lenses, enables a high speed measure with resolution and repeatability due to higher quality.

2. APPLICATIONS OF MICROLENS ARRAY

Microlenses can be used in many applications [2,3,5] such as:

- microlenses for fiber coupling and optical switching;
- microlenses for collimation of lasers diodes;
- microlenses for imaging systems and sensors;
- beam homogenizers for lasers und illumination systems;
- array optics featuring high precision;
- for the best imaging characteristics (aspherical lenses);
- simplified alignment and assembly (planar substrates

With a large used is refractive microlenses [5], in special in miniaturization of an optical system and reduction of alignment, being produced in the form of arrays (fields) on planar substrates (wafers). Refractive microlenses are created from synthetic fused silica or silicon in a cleanroom environment using the highly sophisticated processes of the semi-conductor industry as photolithography, plasma etching, which assured accuracy production of complex array optics and higher optical quality of microlenses.

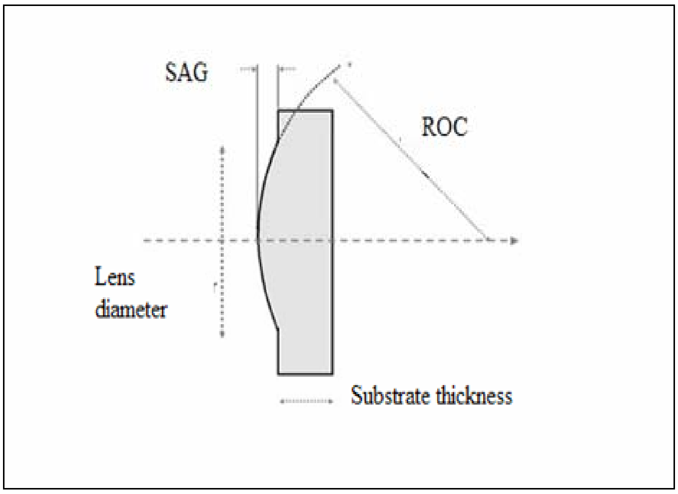


Fig.2. Parameter of refractive lens.

Refractive microlenses [3,5] are characterized from: lens diameter-*D*, focal length-*f*, sag at the lens vertex-*SAG*, refractive index-n_1, radius of curvature-*ROC*, conic constant-*k* and numerical aperture-*NA*. For spherical lens profiles, the conic constant k = 0; for parabolic profiles, k = -1 and for hyperbolic profiles, $k = -(n_1)^2$. The main formulas [5] are:

$$f = \frac{ROC}{n_1 - 1} \tag{1}$$

$$NA \approx \frac{D}{2f} \tag{2}$$

$$SAG = ROC - \sqrt{ROC^2 - 1/4\, D^2} \tag{3}$$

$$ROC = \frac{D^2}{8SAG} + \frac{(k+1)}{2} SAG \qquad (4)$$

High-grade microlenses [5] are almost fabricated synthetic fused silica (n_{589nm} = 1.458) or silicon ($n_{1.5\mu m}$ = 3.478). Fused silica microlenses can be used in the full wavelength spectra from UV (ultra violet) to IR (infrared), silicon microlenses are designed for the infrared wavelength range : λ=(1.2 - 15)μm (fig.3).

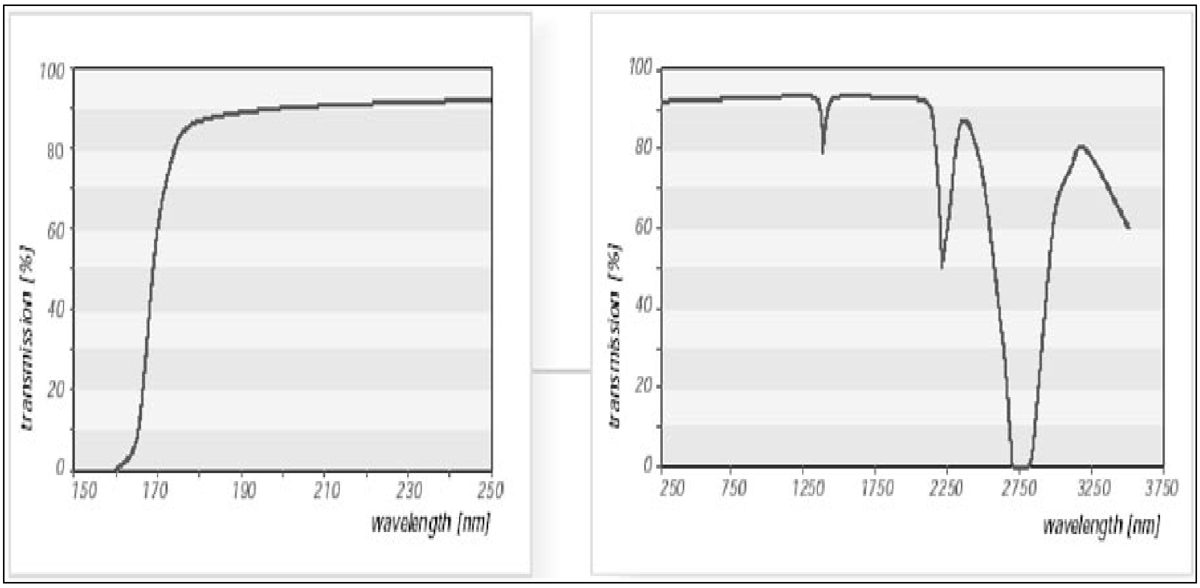
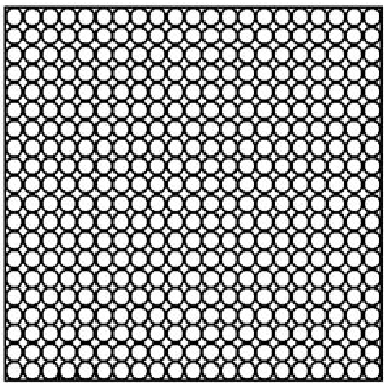


Fig.3. Typical transmission of Schott Lithosil™ Q1 including Fresnel reflection losses (10 mm thickness).

With all these descriptions of characteristics and parameters of microlens array would be presented in following some types of microlenses array in dependence of material fabrication and its application [5].

Tab.1. Microlens Array,-Fused Silica,**Type FC-Q-100 Square**

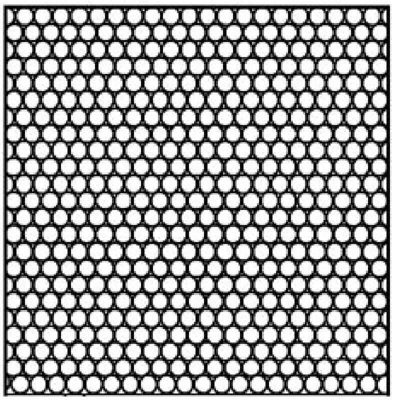
FC-Q-100 Square	
Applications	Fiber optics, lasers, sensors
Substrate material	Fused silica
Refractive index	1.561 at 248 nm 1.457 at 633 nm 1.444 at 1550 nm
Substrate thickness	1.2 mm
Array type	Square
Lens spacing (Pitch)	100 μm
Lateral precision	± 0.25 μm
Lens type	Refractive, Plano-convex
Lens diameter	95 μm



I I Lens spacing in the array (Pitch) = 100 μm

Tab.2. Microlens Array,-Fused Silica,**Type FC-Q-250 Hex**

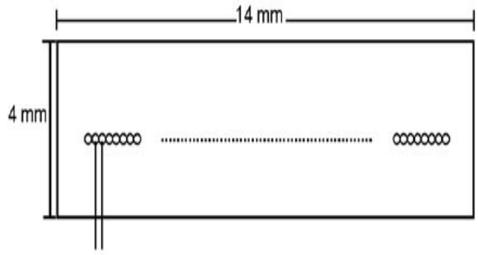
FC-Q-250 Hex	
Applications	Fiber optics, lasers, sensors
Substrate material	Fused silica
Refractive index	1.561 at 248 nm 1.457 at 633 nm 1.444 at 1550 nm
Substrate thickness	1.2 mm
Array type	Hexagonal, densely packed
Lens spacing (Pitch)	250 µm
Lateral precision	± 0.25 µm
Lens type	Refractive, Plano-convex
Lens diameter	95 µm



I I Lens spacing in the array (Pitch) = 250µm

Tab.3. Microlens Arrays, Fused Silica, for Fiber Optics

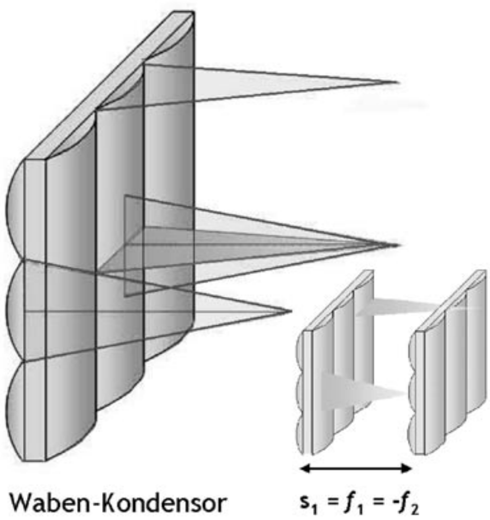
FC-Q-250, 1x48, ROC 330 µm	
Applications	Fiber optics, lasers, sensors
Substrate material	Fused silica
Refractive index	1.561 at 248 nm 1.457 at 633 nm 1.444 at 1550 nm
Substrate thickness	0.9 mm
Array type	linear, 1 x 48 Linsen
Lens spacing (Pitch)	250 µm
Lateral precision	± 0.25 µm
Lens type	Refractive, Plano-convex
Lens diameter	240 µm
Coating, both sides	1250 to 1650 nm



Lens spacing in the array (Pitch) = 250µm

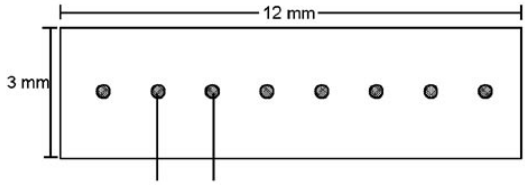
Tab.4. High-Power Beam Homogenizers

CC-Q-300	
Applications	Beam homogenizers
Substrate material	Fused silica
Refractive index	1.561 at 248 nm 1.457 at 633 nm 1.444 at 1550 nm
Substrate thickness	1.2 mm
Array type	Crossed cylinder lenses
Lens spacing (Pitch)	300 µm
Lateral precision	± 0.25 µm
Lens type	Refractive, Plano-convex, Cylindrical
Lens profile	Paraboloid
Uniform distribution of beam	Flat-Top



Tab.5. Silicon Microlens Arrays, for Fiber Optics

FC-Si-1250, 1x8, silicon	
Applications	Fiber optics, lasers, sensors
Substrate material	Silicon
Refractive index	3.478 at 1550 nm
Substrate thickness	0.5 mm
Array size	12.0 x 3.0 mm
Array type	linear, 1 x 8 lenses
Lens spacing (Pitch)	1250 µm
Lateral precision	± 0.25 µm
Lens type	Refractive, Plano-convex
Lens diameter	500 µm
Coating, both sides	1250 to 1650 nm



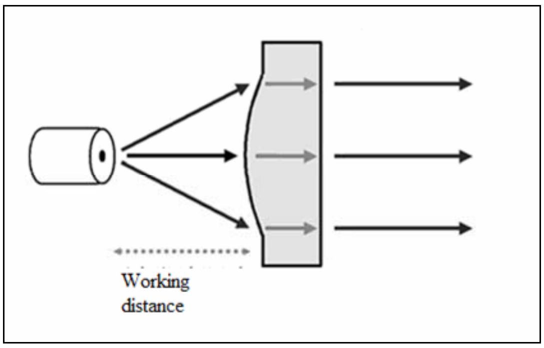
Tab.6. Type of Silicon Microlens Array for Fiber Optics

Type	ROC	Wave-length (nm)	Numerical aperture	Conic constant	Array size (mm)
FC-Si-1250	900 µm	1250–1650	0.68	-3.3	12x3
FC-Si-1250	950 µm	1250–1650	0.65	0	12x3
FC-Si-1250	2350 µm	1250–1650	0.26	-4	12x3

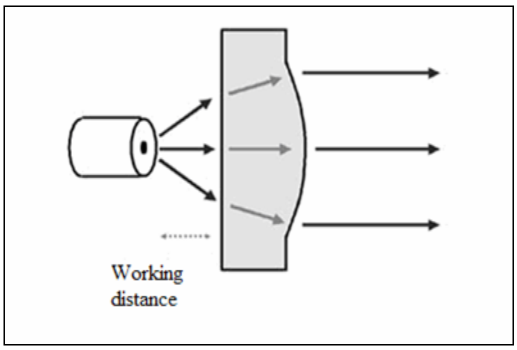
The main role of microlenses in an optical system is collimation and focusing of light beams or imaging an object in a focal plane.

In optical communication engirneering, a microlens array is used to image the light of a fiber bundle onto an array of micro-mirrors. A second microlens array couples the deflected light of the individual data channels back into a fiber array. The high precision of the lateral array dimensions (better than ±0.25 µm) allows a very accurate fiber-to-lens positioning of many channels in one alignment step. The high-class lens quality and the exceptional lens-to-lens uniformity ensure optimal coupling efficiencies for all optical channels in parallel.

The aspherical lens profiles are used to minimize the spherical aberrations for different optical configurations as vertical incident light.



a. Lens on object side



b. Lens on image side

Fig.4. Way beam through microlens array.

As an observation its can emphasize that small pupil diameter of microlenses requires careful design of optimal systems, taking into consideration diffraction effects, light scatter and mechanical tolerances.

3. CONCLUSIONS

This paper has presented some types of microlens arrays with its parameters and materials for fabrication, and certain application. A main role in microlens array is got by its radius of curvature which must be controlled for assured quality image and preventing loss signal.

Advances in 3D measurement techniques, such as optical profiling, have given engineers, process designers and quality control professionals a significantly improved toolkit for describing surfaces.

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