Short Communication

Applications of periodically structured surfaces on glass[1)]

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Periodic structures on glass surfaces with dimensions much smaller than a micron can be used in very different applications such as antireflective surfaces and grating couplers for biosensors. The manufacturing technology is briefly described.

Anwendungen periodisch strukturierter Oberflächen auf Glas

Periodische Strukturen auf Glasoberflächen, die Dimensionen deutlich kleiner als ein Mikrometer aufweisen, können für so unterschiedliche Anwendungen wie Antireflexoberflächen und Koppelgitter für Biosensoren eingesetzt werden. Das Herstellungsverfahren wird kurz beschrieben.

1. Introduction

Periodically structured surfaces for optical applications possess different properties depending on the ratio of period to wavelength. These properties vary strongly near the resonance range, i.e. when the period is of the same order of magnitude as the wavelength of the incident radiation.

For larger periods than the wavelength of light, the surface acts as a refractive grating: One or more higher orders of refraction propagate and can be used for spectroscopy, as sensors or simply as redirected light. If the period structure is smaller than the wavelength of light, the surface acts as an antireflection coating. The antireflection principle was derived from observing the eyes of nocturnally active moths. In 1967, Bernhard [1] found structures on their cornea which are very similar to a periodic hexagonal surface-relief grating with periods of about 230 nm. Since the imitation of the moth-eye structures has been facilitated by holographic exposure with powerful lasers, surface-relief structures have been investigated with increasing intensity around the world for use as antireflection "coatings" [2 to 8]. The main obstacles are the production of large-area master structures and the replication in materials which remain stable when exposed to outdoor conditions.

A particular advantage of periodic surface structures is that they can be reproduced very cheaply by embossing processes. The demand for inexpensive components of high optical quality is also very high in other application areas.

In biological analysis, a number of optical analytical procedures without marker substances are based on optical waveguides, for which gratings are used to couple the light in and out (e.g. [9 and 10]). Because this application demands a stable substrate material (chemically inert and with a constant refractive index), it is particularly attractive to use inorganic glass. Compared to the hot embossing technology already used for polymer optics, the embossing of glass or stable coatings on glass is very much more difficult.

Solving this problem for antireflective surfaces, coupling gratings and further applications is the aim of the Fraunhofer consortium "Optically Functional Surfaces".

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2. Production of master structures and replication tools

The master structures are produced by holographic exposure of photoresist. Two expanded laser beams are superimposed at a certain angle to each other. The light intensity in the interference pattern from the superposition is sinusoidally modulated and is used to expose the photoresist. During development, the amount of photoresist removed corresponds to the exposure intensity and a surface-relief grating results. Crossed gratings can be made by rotating the substrate by 90° between two exposures (figure 1).

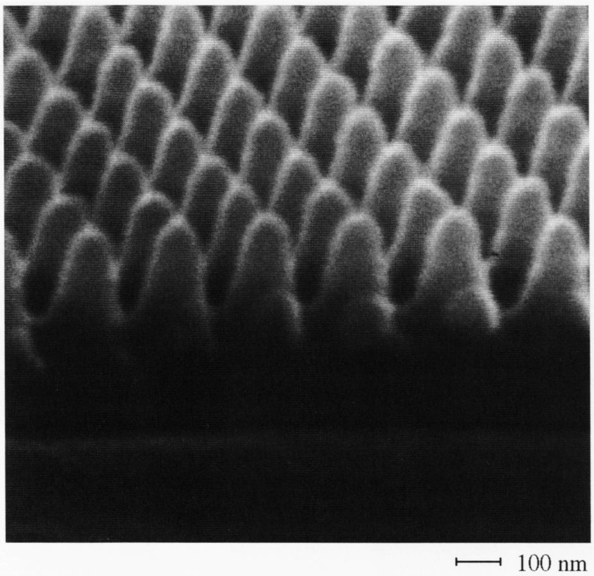

Figure 1. SEM image of a master structure in photoresist.

To manufacture embossing tools, the photoresist can be either reproduced galvanically in nickel or transferred by etching techniques to embossing materials which can resist high temperatures. These embossing tools are used directly to emboss sol-gel layers on glass or glass itself.

3. Summary and outlook

Surfaces with "moth-eye" antireflective structures are characterized by very low reflectance values over a wide spectral range, which strongly resemble the natural model (figure 2). Significant progress has been made in increasing the homogeneously structured area of both the master structure and the coatings for replication. At present, homogeneous masters can be prepared over an area of about 1200 cm^2.

Homogeneous replication in Ormocer coatings has been demonstrated on areas up to (30×42) cm^2 to date. Moth-eye structures have been replicated successfully in inorganic sol-gel coatings for the first time. A desirable side effect of periodic surface structures for antireflection purposes is their improved response to cleaning with water due to their effect on wetting behaviour.

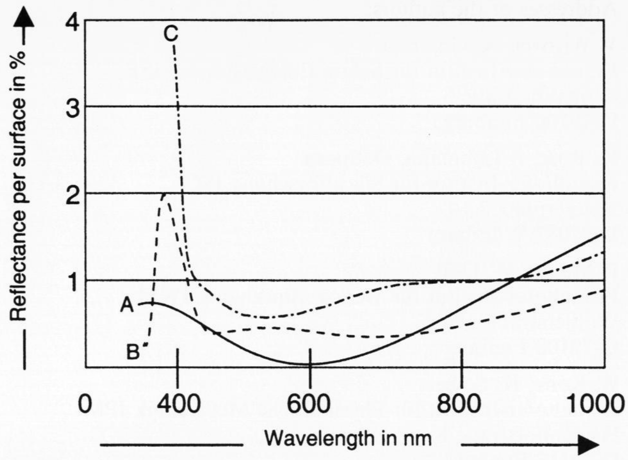

Figure 2. Experimental results and theoretical value for the genuine moth eye; curve A: theoretical value for the structured cornea of nocturnally active moths, curve B: "artificial moth eye" in an Ormocer layer on glass, curve C: "artificial moth eye" in a purely inorganic layer on glass.

Coupling gratings with good optical quality have been produced in sol-gel coatings on glass or by hot embossing in glass. In particular, progress has been made in the glass embossing technology. It is now possible to emboss at a rate of one per second. This is an essential prerequisite for economic application of the biological analysis techniques mentioned above.

4. References

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