Practical realization of reflective metallic coatings for planar-integrated free-space optics (PIFSO)

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We discuss a novel method to realize composite Al-Ag-Al coatings with high reflectance and good adherence to glass substrates. It is based on an adhesive underlayer with sparse spatial support and on „anchoring“ ditches that surround optical components and prevent delamination. The method is technologically simple and ideal for planar-integrated free-space optics.

1 Indroduction

In planar-integrated free-space optics (PIFSO) [1] the systems approach of which is shown schematically in Abb.1 signals may have to bounce up and down a considerable number of times inside a planar transparent substrate to reach their destinations. To obtain a high coupling efficiency it is therefore mandatory to cover the optical elements with a high-reflectance coating. Thin metal films are often used and prefered to dielectric mirrors because they can be deposited much easier and at lower cost by means of physical vapor deposition.

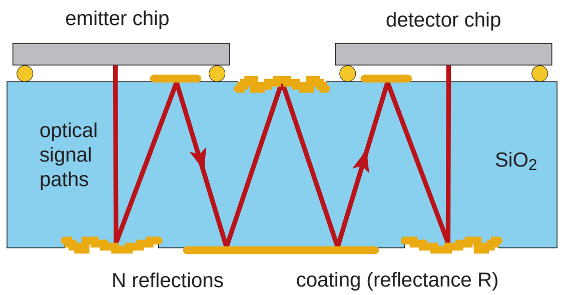

Abb. 1 *PIFSO systems approach.*

As one can see from Tab.1 Al is well-suited for its chemical passivity and its good adherence to fused silica, however, its reflectance is relatively low; in the wavelength region around 850nm that is particularly important for short-range optical communication only about 80% of the impinging light is reflected. Ag, by contrast, has a high reflectance of about 99% but lacks the other two properties.

	Al	Ag	dielectric stack
reflectance	—	+	+
adherence	+	—	+
chem. stability	+	—	+
effort / cost	+	+	—

Tab. 1 *Properties of different reflector types.*

2 Novel composite coatings

The idea therefore is to use composite Al-Ag-Al coatings that combine the advantages of both metals [2]. Abb.2 shows the proposed configuration. The sandwiched Ag layer is the main reflector while the two Al layers serve as adhesive underlayer and as protective overlayer, respectively. To keep its influence on the overall reflectance low the Al underlayer is thereby not continuous. Instead it is reduced to sparsely and randomly distributed tiny patches that cover only a small fraction of an optical component and serve as discrete „bonding pads". To prevent delamination of the Ag layer from the mirror edges narrow ditches are etched into the substrate around each component in which the coating is „anchored“. The ditches also enable an hermetical sealing of the sensitive Ag layer from the environment.

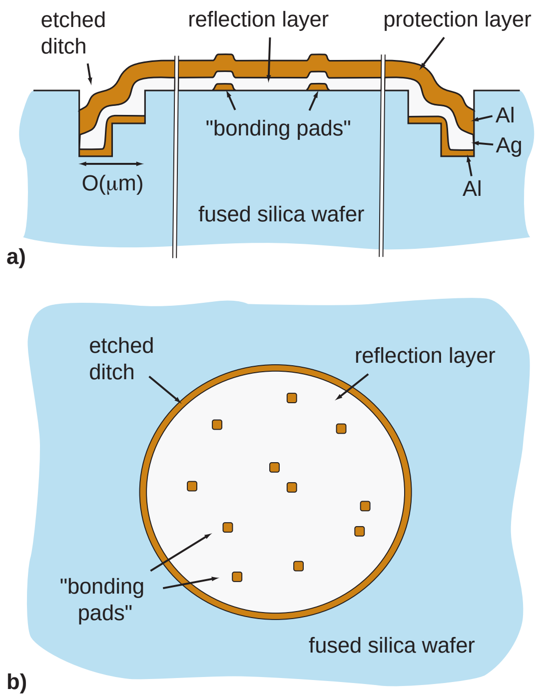

Abb. 1 *Proposed Al-Ag-Al composite reflectors.*

3 Optical properties

The spatially inhomogeneous interface of the proposed comosite reflectors needs to be interpreted as a diffractive optical element that introduces small amplitude and phase modulations on an impinging beam. These modulations are due to the different reflectances R and phase shifts ϕ at the metal-glass interface for Ag and Al and are governed by the mathematical relations

$$R = \frac{(n_0 - n_1)^2 + k_1^2}{(n_0 + n_1)^2 + k_1^2} \qquad (1)$$

$$\tan\phi = \frac{2n_0 k_1}{n_0^2 - n_1^2 - k_1^2} \qquad (2)$$

n and k thereby symbolize the real and imaginary parts of the complex refractive indices of the involved materials. As a consequence, some light is diffracted into unwanted orders which is tantamount to a reduced effective reflectance of the coating. This effect was estimated quantitatively in computer simulations by calculating the accumulated intensity of all non-zero orders in the power spectrum for plane-wave impinging beams. We find that the diffracted light is rather uniformly distributed over all non-zero orders (cf. Abb.3) and that the loss is typically less than an order of 10^{-4} relative to the total intensity of the impinging beam which means it is negligible in practice.

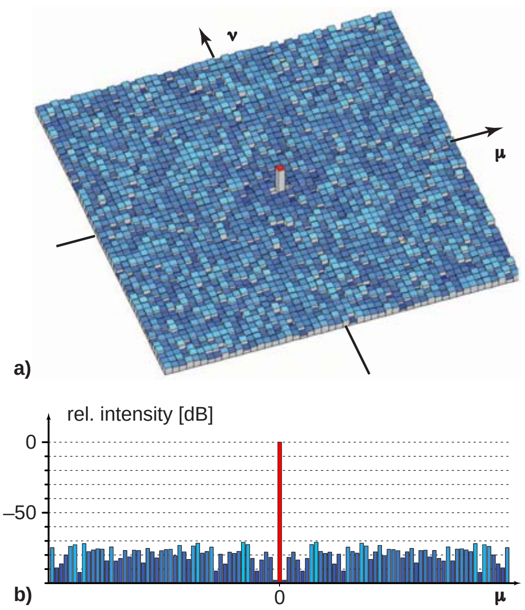

Abb. 2 *Simulated power spectrum of a plane wave after reflection from a composite Al-Ag-Al mirror. .*

4 Fabrication

The fabrication requires two lithography and evaporation steps. In the first step an underlayer of sparsely and randomly distributed Al patches is deposited (cf. Abb.4). In the second step the actual

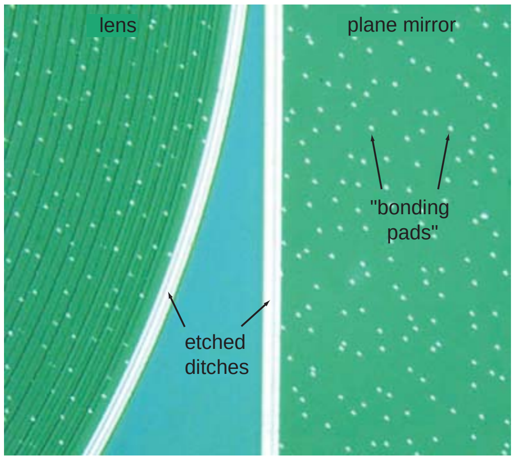

Abb. 3 *First fabrication step: Deposition of the sparsely distributed Al „bonding pads".*

Ag reflection layer and the Al protection overlayer overlayer follow. The fabrication complexity of a PIFSO module is thereby usually not increased.

5 Experimental evaluation

In optical experiments the expected superior perfomance of composite Al-Ag-Al reflectors was confirmed. The increase in reflectance is already visually observable (Abb.5a). Measured R-values were typically around 98% (cf. Abb.5b).

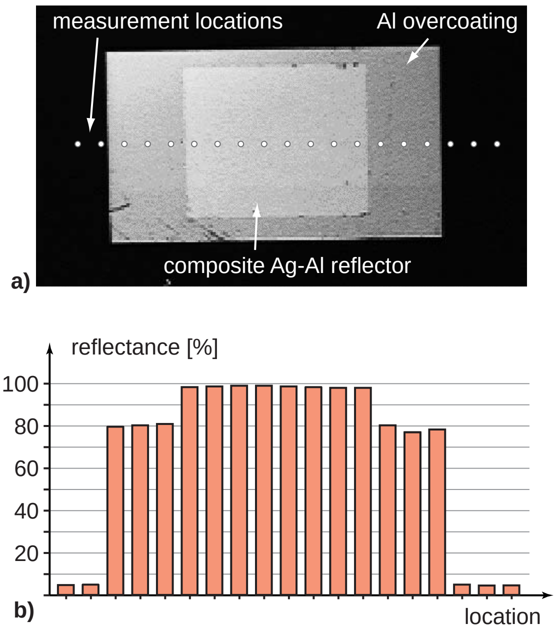

Abb. 4 *Reflectance measurements.*

References

[1] M. Gruber, J. Jahns, "Planar-integrated free-space optics – from components to systems", Ch. 13 in: J. Jahns, K.-H. Brenner (Eds.), Microoptics–from technology to applications, Springer, New York, 2004.

[2] M. Gruber, T. Seiler, A.C. Wei, " High-reflectance composite metal coatings for planar-integrated free-space optics", Appl. Opt., accepted.