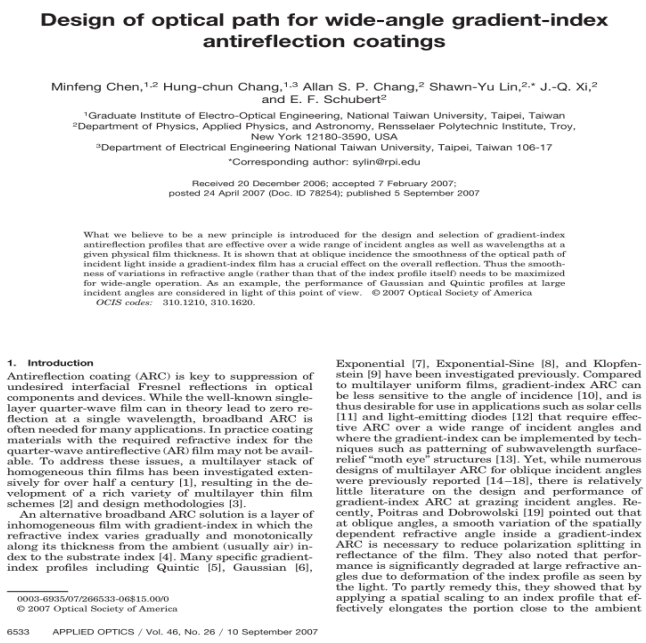
Design of Optical Interference Coatings (Mcgraw-Hill Optical and Electro-Optical Engineering Series)



Design of optical path for wide-angle gradient-index antireflection coatings

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What we believe to be a new principle is introduced for the design and selection of gradient-index antireflection profiles that are effective over a wide range of incident angles as well as wavelengths at a given physical film thickness. It is shown that at oblique incidence the smoothness of the optical path of incident light inside a gradient-index film has a crucial effect on the overall reflection. Thus the smoothness of variations in refractive angle (rather than that of the index profile itself) needs to be maximized for wide-angle operation. As an example, the performance of Gaussian and Quintic profiles at large incident angles are considered in light of this point of view. © 2007 Optical Society of America
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1. Introduction

Antireflection coating (ARC) is key to suppression of undesired interfacial Fresnel reflections in optical components and devices. While the well-known single-layer quarter-wave film can in theory lead to zero reflection at a single wavelength, broadband ARC is often needed for many applications. In practice coating materials with the required refractive index for the quarter-wave antireflective (AR) film may not be available. To address these issues, a multilayer stack of homogeneous thin films has been investigated extensively for over half a century [1], resulting in the development of a rich variety of multilayer thin film schemes [2] and design methodologies [3].

An alternative broadband ARC solution is a layer of inhomogeneous film with gradient-index in which the refractive index varies gradually and monotonically along its thickness from the ambient (usually air) index to the substrate index [4]. Many specific gradient-index profiles including Quintic [5], Gaussian [6], Exponential [7], Exponential-Sine [8], and Klopfenstein [9] have been investigated previously. Compared to multilayer uniform films, gradient-index ARC can be less sensitive to the angle of incidence [10], and is thus desirable for use in applications such as solar cells [11] and light-emitting diodes [12] that require effective ARC over a wide range of incident angles and where the gradient-index can be implemented by techniques such as patterning of subwavelength surface-relief "moth eye" structures [13]. Yet, while numerous designs of multilayer ARC for oblique incident angles were previously reported [14–18], there is relatively little literature on the design and performance of gradient-index ARC at grazing incident angles. Recently, Poitras and Dobrowolski [19] pointed out that at oblique angles, a smooth variation of the spatially dependent refractive angle inside a gradient-index ARC is necessary to reduce polarization splitting in reflectance of the film. They also noted that performance is significantly degraded at large refractive angles due to deformation of the index profile as seen by the light. To partly remedy this, they showed that by applying a spatial scaling to an index profile that effectively elongates the portion close to the ambient

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