

Chapter 1

Introduction

1. INTRODUCTION

Heat transfer occurs via radiation, conduction, and convection. When the radiative exchange is significant - which holds true for many important applications - one can achieve energy efficiency by exploiting surfaces with spectral selectivity. This term is taken to imply that the radiative properties (i.e., the absorptance A , emittance E , reflectance R , and transmittance T) are qualitatively different within different parts of the electromagnetic spectrum. Spectral selectivity can be obtained by use of coatings onto substrates that are either transparent or opaque metallic, or by treating the surfaces of the substrates.

The optical properties are connected to one another at each wavelength λ by the general relations

$$A(\lambda) + R(\lambda) + T(\lambda) = 1, \quad (1-1)$$

$$E(\lambda) = A(\lambda). \quad (1-2)$$

Both relations follow from energy conservation. Equation (1-2), known as Kirchhoff's law, states that at a given wavelength the absorptance is equal to the emittance for matter in thermo-dynamical equilibrium.

This Tutorial Text considers three important applications of selective coatings and surface treatments. These are for

- selective transmission to achieve energy efficient windows with static or dynamic properties;
- selective absorption of solar energy in order to produce useful heat; and
- radiative cooling by selective infrared emission toward the clear sky.

Section 2 contains some basic material that must be covered before we can turn to the selective coatings and surface treatments. It treats thin film optics, models for dielectric functions of homogeneous and nonhomogeneous materials, and techniques to evaluate dielectric functions from optical measurements. Section 3 introduces spectral selectivity for energy efficiency and solar energy utilization by presenting the radiative properties pertinent to our ambience and giving formulas for computing suitably integrated optical quantities. Section 4 is devoted to window coatings of different types and covers the spectral selectivity demanded for different climates. Reviews are given for coatings with static and dynamic properties; they embrace noble-metal-based and doped-oxide-semiconductor-based coatings, as well as electrochromic multilayer coatings and thermo-

chromic coatings for “Smart Windows.” Section 5 takes up surfaces for selective absorption of solar energy. Such surfaces are needed in efficient solar collectors. We cover the required spectral selectivity and give a review of coatings and surface treatments. Section 6, finally, dwells on surfaces for radiative cooling to low temperatures. The resource for radiative cooling under a clear sky, and materials with infrared-selective emission are discussed. Three case studies are appended. They give in-depth discussion of the optical properties of Au coatings made by ion-assisted evaporation, e-beam evaporated $\text{In}_2\text{O}_3:\text{Sn}$ coatings, and coevaporated $\text{Co-Al}_2\text{O}_3$ composite coatings. The first two case studies regard window coatings, while the last one regards a solar collector coating. The case studies are not as restrictive as one might initially believe but illustrate salient features of surfaces based on noble metal coatings, on heavily doped oxide semiconductor coatings, and on metal-insulator composite coatings. For convenience, a primer on large-scale coating technology is included as appendix D. The reference list at the end of the text contains books, review articles and - to a limited extent - original scientific papers of particular relevance. General reviews of spectrally selective coatings and surface treatments for energy efficiency and solar energy utilization are given in Refs. 1-8.