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Solar material protection factor (SMPF) and solar skin protection factor (SSPF) for window panes and other glass structures in buildings

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Abstract

The two quantities solar material protection factor (SMPF) and solar skin protection factor (SSPF) are introduced in order to measure and calculate the capability of glass to protect indoor materials and human skin from degradation caused by the solar radiation. Comparison of the SMPF and SSPF values for different glass fabrications enables one to select the most appropriate glass material for the specific buildings. Numerical examples are shown with measurements and calculations carried out on various glass materials, including two electrochromic window (ECW) devices, and several two- and three-layer window pane combinations. Visibility levels at various protection degrees are also given.

Keywords: Material; Skin; Protection factor; Window pane; Glass; Building; Solar radiation; Ultraviolet light; Visible light

1. Introduction

Since early times when man discovered and began utilizing the glass material in their buildings, they have had efficient means to let sunlight into the buildings and at the same time be protected from harsh weather in the form of rain and wind outside. This has provided mankind with buildings where daylight and solar heat have given comfortable living and working spaces in a protected environment. With the following citation we may go back 4000–6000 years in history [1]:

> *Who, when he first saw the sand or ashes … melted into a metallic form … would have imagined that, in this shapeless lump, lay concealed so many conveniences of life? … Yet, by some such fortuitous liquefaction was mankind taught to procure a body ... which might admit the light of the sun, and exclude the violence of the wind …*

As the use of window panes and glass structures in buildings have become more and more widespread and extensive up throughout the years, the construction design and glass-material properties have become more important. This is also strengthened by the increasing tendency of often employing rather large glass areas in today's buildings.

Glass with material additives and different surface coatings is tailor-made and chosen in order to fulfil the various requirements for the specific buildings. The glass and window properties are selected with respect to several, often contradictory, considerations. Generally, a window is supposed to let in as much daylight as possible, give comfortable luminance conditions, give satisfactory view out of (and often into) buildings, transmit minimum heat from the interior to the exterior in order to reduce the heating demand, transmit solar radiation from the exterior to the interior in order to reduce the heating demand (i.e., in winter), shut off solar radiation by reflection, which otherwise might cause too much heating, not induce air current problems or give a poor thermal comfort and not induce unacceptable interior or exterior water condensation.

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As is seen from the above, very much concern is taken regarding the energy aspects of window panes. The energy transfer in windows consists of sun radiation, thermal (infrared) radiation, thermal conduction in solids and gases and gas convection. The glass materials with surface coatings and window details are adapted to the actual building type and function, e.g., office building, hospital, family dwelling etc. The energy from the solar radiation will diminish the need for heating, but at the same time the energy costs due to cooling demands should be kept as low as possible. The measurement and calculation of quantities such as solar transmittance, solar reflectance and solar factor is important in this respect. The solar factor (SF) is the sum of the solar transmittance and the emitted infrared radiation inwards the building, i.e., the total solar energy transmission through the glazing.

One aspect with window glass panes, however, has not been emphasized in the same extent. The solar radiation is responsible for part of the degradation of the building materials, especially organic matter where the chemical bonds may be broken up by the more energetic parts of the solar spectrum, i.e., ultraviolet (UV) light. A substantial part of the UV light is blocked by the glass itself, but nevertheless a significant amount of UV light passes through the glass and into the buildings. This transmitted UV light affects both materials and living species inside the buildings. Typical examples may be fading, discolouration and degradation of books in book shelves (e.g., in libraries) and other paper materials, wall paintings and exhibits (e.g., in museums), wood materials in walls, floor, ceiling, window frames, etc., plastic materials and surface painting in various building structures and equipment, furniture and carpets. Other examples may be green plants and flowers (e.g., in family dwellings, atriums with large glass areas, greenhouses), livestock and pet animals in various buildings and human beings in situations with larger exposed skin areas (in winter gardens, indoor swimming and recreation areas with large glass facades, etc.). The desire to be able to look in and out of windows is in direct contradiction to the material and skin protection abilities, especially the material protection, as we will see later in this work. Electrochromic window (ECW) devices, which are able to control the solar radiation passage by varying the applied voltage, might also be of interest in this respect. Protection of human skin from sunlight, especially the short-wave radiation, is also interesting in other structures than buildings, e.g., in automobiles.

In order to quantify and compare the ability of different glass materials (with and without coating) to protect indoor building materials and articles, and skin of human beings, we will introduce the two quantities in this work, solar material protection factor (SMPF) and solar skin protection factor (SSPF), for window panes and other glass structures in buildings.

2. Solar radiation

The solar radiation at the earth's surface is roughly located between 300 and 3000 nm (0.3 and 3 μm, respectively), where the visible (vis) light lies between 380 (400) and 780 nm. UV and infrared (IR) radiation are located below and above the vis region, respectively. The wavelength region between 780 and 3000 nm is called the near infrared (NIR) region. Fig. 1 depicts the solar radiation in outer space and at the earth's surface, both with and without molecular absorption in the atmosphere.

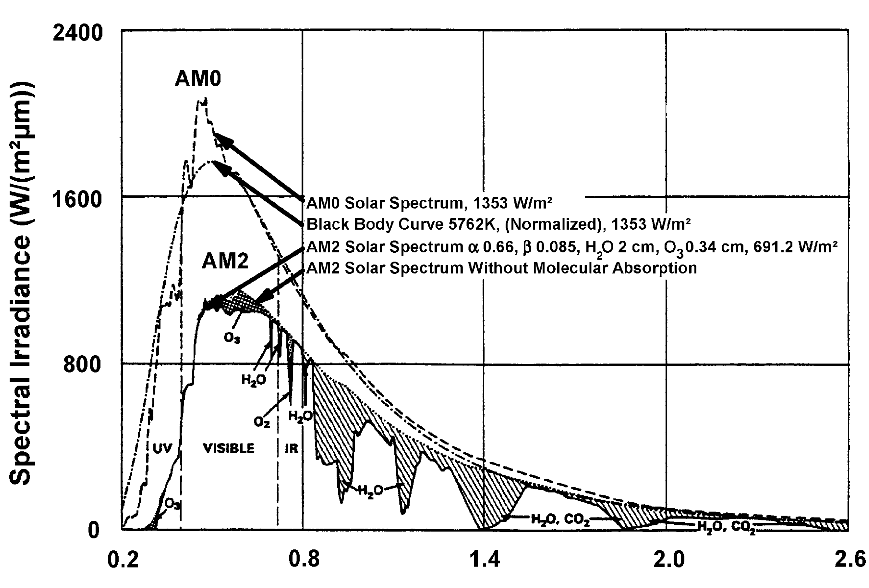

Fig. 1. The radiation from the sun, comparing the AM0 (outer space) and AM2 (at the earth's surface, the sun 30° above the horizon) spectra. The AM2 spectrum is shown both with and without molecular absorption (in O_2, O_3, H_2O and CO_2). Redrawn from Fahrenbruch and Bube [2].