Solar Radiation Energy Regulation by Optical Coating Used in Residential Buildings

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ABSTRACT

The energy distribution of solar radiation and the demand of the residential building environment for lighting and temperature are contradictory to some extent. In order to better meet people's life needs, better control of sun’s light and heat is needed to solve this problem. We use the infrared cutoff filter technology in optical coating to allow visible light to enter residential buildings as much as possible, while minimizing the access of near-infrared light\(^1\).

INTRODUCTION

The sun and water are the basic natural conditions of human reproduction. The light and heat from solar radiation provide good lighting and comfortable temperature requirements for human life. The design of modern residential houses is to use sunlight as much as possible, an important natural resource, to save energy demand. So glass materials are widely used to an unprecedented degree\([1-3]\). Glass Windows allow as much sunlight as possible into the interiors of residential buildings. However, there is a certain degree of contradiction between the energy distribution of solar radiation and human demand for lighting and temperature. Therefore, people hope that the energy distribution of solar radiation can be adjusted according to human needs.

Optical coating technology is an optical branch based on the development of film interference theory. This technology is the most effective method of spectrum adjustment, which solves a wide range of practical engineering problems and has been largely marketed\([4-6]\). At present, optical coating

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applications are gradually penetrating into fields such as solar energy, microelectronics, aviation and nuclear technology, et al. In the field of real estate construction, coating can still exert its characteristic spectral control ability[7,8].

In this paper, based on the characteristics of solar radiation energy distribution and the lighting and temperature requirements of residential buildings, we adopt optical coating technology to adjust solar radiation. In section 2 and 3, we separately introduce the characteristics of solar radiation energy distribution and requirement of lighting and energy in residential buildings. In section 4, we use the infrared cutoff filter in optical coating technology to adjust the solar radiation as required.

SOLAR RADIATION ENERGY DISTRIBUTION

The sun is a source of electromagnetic radiation with a temperature of about 5800K. The extremely wide continuous spectrum of sunlight as well as tens of thousands of absorption lines and emission lines, which is an extremely rich treasure of solar information. Due to the intense absorption of ozone, moisture and other atmospheric molecules in the earth's atmosphere, solar radiation wave less than 0.295 μm and greater than 2.5 μm cannot reach the ground. The range of solar radiation measured on the ground is about 0.295-2.5 micron.

As shown in Fig.1, solar radiation measured on the ground covers the frequency band of ultraviolet ray, visible light and near infrared ray. According to the study analysis, the energy of the solar spectral radiation is 53% in the infrared spectrum (780-2500nm), 44% in the visible band (380-780nm), and only 3% in the ultraviolet band (100-380nm).

Figure 1. Diagram of solar radiation energy distribution on the ground.
REQUIREMENT OF LIGHTING AND ENERGY IN RESIDENTIAL BUILDING

As residential buildings, people always want good lighting and comfortable temperature. Although artificial lighting and air conditioning can also provide these comfortable environment for humans. However, from the perspective of energy conservation, we hope to make the best use of natural resources.

Sunlight on the ground, which includes ultraviolet, visible and infrared light, plays an extremely important role in human health. The sun also provides light and heat, which meet the needs of lighting and energy in human life. If we can make a good control of the solar radiation spectrum, we can achieve the spectral heat and light control of the sun.

As shown in Fig.2, people want to let visible light into residential buildings as much as possible for indoor lighting needs. But for comfortable temperature demand, in the summer, people want as little heat as possible into homes; in winter, people want to keep as much heat as possible in their homes. So according to the character of solar radiation energy distribution on the ground, we should adopt reasonable design to ensure the good light intensity in visible band and the thermal suppression in infrared band.

![Diagram of lighting and energy needs in residential buildings.](image-url)

Figure 2. Diagram of lighting and energy needs in residential buildings.
SOLAR RADIATION REGULATION BY OPTICAL COATING

Optical coating is very natural and appropriate solutions to many optical engineering problems like reduction or enhancement of reflectance, selective spectral filtering of complex optical systems. To the requirement of lighting and energy in residential buildings, we can use infrared cutoff filter (IR filter) structure in optical coating.

IR filter optical coating is a multilayer thin film stack, which is a finite combination of such layers having different film constants about refractive index \( n_i \), extinction coefficient \( k_i \) and thickness \( d_i \). Then based on multilayer film interference analysis and mathematics optimization method, we design an IR filter with the structure as Glass\( | \)TiO\(_2\) (28.71nm)Ag (11.54nm)TiO\(_2\) (28.71nm)\(^3\) Air. TiO\(_2\) material is used to improve the reflectance in the near infrared wavelength region, and fundamentally control the heat of the near-infrared ray into the room. The use of Ag materials is mainly used to absorb a small amount of unreflected near-infrared ray into the room. The corresponding transmittance curve of our design result with different incidence angle are shown in Fig. 3.

We can find that the transmittance of the visible band is over 80% when the incidence angle is less than 60 degrees. But, when the incidence angle is increased to 80 degrees, the transmittance of the visible band is reduced to 50%. In practical application, the angle of sunlight is below 60 degree during the main period of high temperature in every day. So our design can meet the actual environmental requirements. We can also find that the transmittance in the region of 800nm to 1200nm decreases rapidly, while that in the region of 1200nm to 2500nm is almost negligible.

![Figure 3. Transmittance curve of the optical coating used in different incident angle.](image)
In the summer, IR filter attach to the exterior of the window and it can block out about 79 percent of the heat, thus greatly reduces the cooling cost of air conditioning. In winter, IR filter is attached to the interior of the glass window and it can reduce heat loss about 30 percent, thus achieving indoor thermal effect.

Through comparative experiments, we find that the room temperature of the room with optical coating is 3.5 degrees Celsius lower than that of the room without it, when the outdoor temperature is 38-39 degrees Celsius. For two rooms with the same condition of 16 square meters, the comparison experiment of air conditioning energy saving showed that the room with optical coating can save electricity 0.24 degrees per day compared with the room without it.

CONCLUSIONS

In this paper, we adopt the infrared cutoff filter in optical coating technology to adjust the solar radiation spectrum. The infrared cutoff filter consists of silver and titanium dioxide thin films. TiO2 coating material has a high value refractive index in visible band, and Ag coating material has a larger value about the imaginary part of refractive index in infrared band. So our design can maintain the good light of glass in visible band and the thermal suppression in infrared band, which can better meets people's living needs for lighting and temperature.

REFERENCES