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Comparative experimental study on heating and cooling energy performance of spectrally selective glazing

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ABSTRACT

The study aims to evaluate thermal performance of newly developed spectrally selective coated glazing (SS) which has very low near infrared (NIR) transmittance and fairly high visible (VIS) transmittance. The performance of SS was first tested in full scale mock-up test cells and then compared with three types of conventional glazing systems (single low-e, triple low-e and clear). The comparative field test without air conditioning showed that solar gain of SS was less than or similar to the conventional glazing systems due to the low NIR transmittance, which present a potential of cooling energy saving in building application. Based on the field test, the thermal performance of SS was predicted using a building energy simulation. The simulation result showed that SS reduce 21% and 33% of total energy consumption as compared to the glazing with low-e coating and the glazing without coating respectively. The study concluded that SS can achieve lighting energy reduction with high VIS transmittance and cooling energy reduction with both high NIR transmittance and high U-value. Ultimately, SS will be highly applicable in cooling-dominated buildings or climate zone.

1. Introduction

Modern architectures as well as residential buildings prefer big curtain-wall buildings with big window area ratio (window wall ratio of 35–80%) for the purpose of daylighting and view. Such curtain-wall consists of transparent glass in general. A typical ordinary glass has high transmittance as well as low reflectance in the visible (VIS) and near-infrared (NIR) regions, but also has low transmittance and a low reflectance, and thus a high emittance in the far infrared region (Lampert, 1981; Mohelnikova, 2009). As a result, the use of curtain-walls causes a large increase in heating and cooling loads (Qu et al., 2014).

In order to resolve the problem of the glass from this spectral characteristic, many researches on spectrally selective coating have been performed. The term "spectrally selective coating" refers to products that provide daylighting and view along with blocking near infrared radiation that causes heat gain, and it allows a relatively high visible transmittance (Lee et al., 1993).

The film type of spectrally selective coating, which can be easily applied to indoor in existing buildings, have been studied and developed; its performance has been proved in several advanced studies. According to (Alvarez et al., 2005), the reflective film reduced solar heat gain coefficient (SHGC) by 12–20%, whose value varies depending on glazing type, outdoor temperature, and wind speed, and it was analyzed to have effect in reducing cooling load in tropical locations. Another study verified that, in theory, spectrally selective film reduces heat energy exchange by 55% in comparison to traditional double glazing by reflecting or absorbing solar energy in near-infrared radiation regions when applying solar control film (Noh-Pat et al., 2011). In addition, a research was executed to reduce energy consumption by applying the reflective film to inner/outer walls (Joudi et al., 2011, 2013) and roofs (Jo et al., 2010; Synnefa et al., 2007; Wang et al., 2008) of buildings. It was derived to have great effect in reducing cooling load.

On the other hand, research on spectrally selective coating was officially executed while the awareness on energy saving became higher after the oil shock in 1973. The research was executed by subdividing into intrinsic absorber (HfC, ReO_3) (Seraphin, 1979; Seraphin and Meinel, 1993), heat mirror (indium tin oxide) (Granqvist, 1987; Redaelli, 1976) and multilayer absorber (Al_2O_3/Mo/Al_2O_3) (Seraphin, 1979). As mentioned earlier, the positive effect of spectrally selective coating on building load reduction was proved, and thus a new energy policy was established to apply low-emissivity coating to windows of almost all buildings in Germany in 1995 (Schaefer et al., 1997). Low-emissivity coating has the spectrally selective characteristic of the NIR region, and it also block radiative heat exchange with low emission. Therefore, fur-

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ther studies on spectrally selective coating in building sector were mainly focused based on low-emissivity coating.

Although there are many positive results – for example, low-e emissivity glass of silver coating type reduces 17–22% of the cooling load according to (Lee et al., 1993) – the use of low-solar-gain low-emissivity coating without considering the weather condition can increase the heating energy consumption in the Northern Climate Zone (Carmody et al., 2004), while the thermal performance of low-emissivity is pointed out as a weakness in hot climates (Hee et al., 2015; Kim et al., 2008).

Therefore, recent studies have been performed on spectrally selective coating without the low-emissivity function. A recent study (Curcija et al., 2015) on the energy saving potential of liquid-applied absorbing films found that the greatest energy saving can be achieved by applying liquid-applied absorbing film in contrast to reflective films when applying selective coating films to the outside double glazing in a retrofitted building located in moderated climate zone (in St. Louis). However, the study concluded that it is realistically not easy to apply the film to the outside, and the quality, durability, and aesthetics must be considered in application.

This study assesses the performance of tungsten-based spectrally selective coated glass (hereinafter referred to as "SS") to resolve issues related to quality and durability that the existing absorbing film possesses during site construction by direct coating on glass in slot die method. To do so, the study first experimentally compared the performance of SS under identical condition and then analyzed the annual energy performance using building performance simulation.

When it comes to the experiment, four highly insulated mock-up test cells of identical specifications were fitted with SS and multiple layers of three glass products commonly used in the market today, and an experiment was conducted under reproduced field conditions. The mock-up test cells were sophisticatedly built to create heat conditions that closely resemble the actual field heat conditions, and fitted with four sets of glazing of identical specifications. A calibration of the initial experimental condition was then performed. After verifying the initial experimental conditions, the glazing of the four control groups was then interchanged, and a comparative experiment on cooling and heating was conducted under identical experimental conditions. Based on the result of these experiments, annual heating and cooling energy performance of SS combined with high-solar-gain low-emissivity glass was predicted using the building energy simulation.

2. Optical properties of glazings for performance assessment

While market demand for window glass with a selective sunlight penetration technology has been increasing, and a wide range of functional glasses has become available. Low-E glass is either hard-coated with the chemical vapor deposition (CVD) technique,

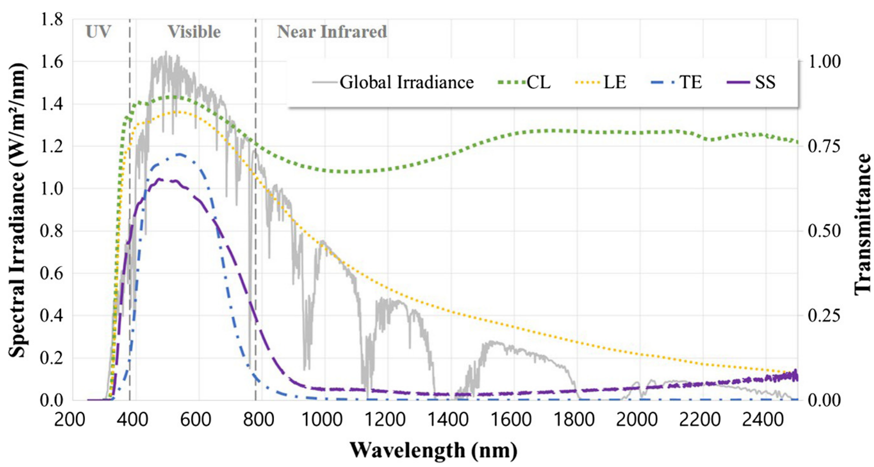

Fig. 1. Optical properties of single SS and conventional glasses.

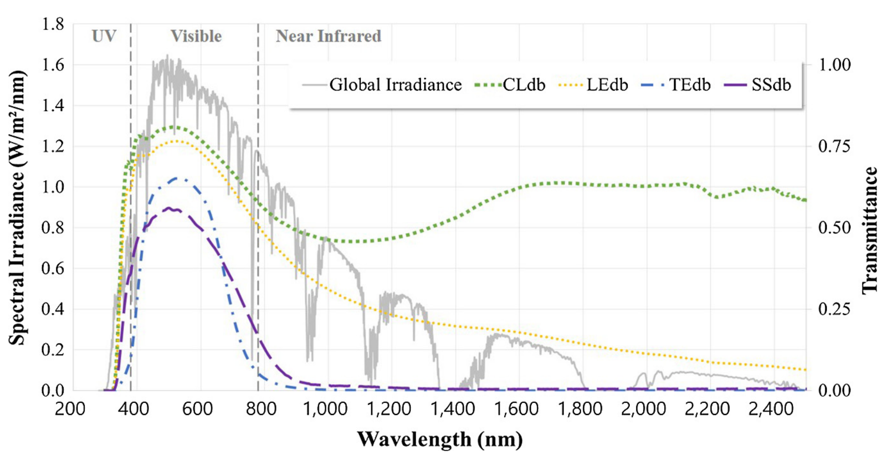

Fig. 2. Optical properties of multi-layer double glazing systems.

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