博 士 論 文 の 内 容 の 要 旨

氏名	CUI LINA
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論文題目	Development and applications of high-performance passive cooling nanocomposite films for energy consumption saving (省エネ用高性能パッシブクーリングナノ複合フィルムの開発と応用に関する研究)

（博士論文の内容の要旨）

Energy expenditure in buildings and transportation is about 63% of global energy consumption. It is reported that temperature regulation for buildings and automobiles takes 60% and 23-41% of their total energy expenditure, respectively, leading to excessive greenhouse gas emissions. One of the strategies for cooling space without any kind of energy input to a special cooling system is to use passive cooling films which has attracted plenty of attentions in recent years. In this dissertation, flexible spectrum selective transparent passive cooling films were developed using zinc oxide (ZnO) nanoparticles (NPs) dispersed in low-density polyethylene (LDPE). Their basic mechanical, thermal, and optical properties and cooling performance were systematically studied in different applicating conditions with variation in the intensity of solar radiation, the ratio of window area to enclosed cooling volume, and shielding ratio of visible (Vis) light.

First, flexible spectrum selective transparent ultraviolet (UV)-shielding films were fabricated by casting method, which uniformly dispersed virgin ZnO NPs in LDPE. The critical conditions for film fabrication, such as casting temperature, LDPE concentration in the solution, dissolution time, NP concentration, and post hot press cooling processes, are systematically studied. Ideal films were successfully fabricated with well dispersed NPs and could completely shield UV light while allowing hi gh transmissivity for the Vis and infrared (IR) photons. The basic property characters of membrane like dispersion of NPs in the films, transmissivity, thermal property, and tensile strength were tested high transmissivity for the Vis and IR photons. The basic property characters of membrane like dispersion of NPs in the films, transmissivity, thermal property, and tensile strength were tested.

Passive cooling performances of spectrum selective films were evaluated with a self-made passive cooling test system, designed with the consideration of actual engineering application. For detecting the influence of the intensity of solar radiation, 24 h temperature monitoring of the cooling performance showed that the temperatures in the testing boxes were raised as the solar irradiation intensity increased in

daytime. Under a fixed ratio of volume vs window area of the test space, the 6%-ZnO film had the largest temperature reduction (ΔT) compared with the temperature of the control box reaching 8.84 ºC, with a corresponding cooling power of 361 W/m^2. It was also observed that the films had cooling effect at night, reaching 1.41 ºC at mid-night, compared with the temperature of the control box too.

The cooling performance of films was influenced by volumes per unit window area or specific volume (SV). Like cars, commercial offices and common residentials, which has different SV, are constructed with windows for daylighting and good scene. The testing results showed that temperature reduction compared with the control, ΔT (up to 14.95 ºC), of the films decline exponentially initially and then levels-off as SV increases. An empirical model is proposed for the relationship between ΔT and SV according to the actual engineering applications, which guides for practical end uses. Furthermore, SVs of passenger cars and office buildings are found to be located within the most sensitive range of the ΔT-SV curve of our films. The regression equation of cooling performance with different shielding ratio of Vis showed liner relationships. Data showed that the better Vis-shielding effect of the films, the better cooling effect of films performed.

Therefore, our cooling film can be highly beneficial for energy saving in passenger cars and large window commercial offices. Meanwhile, even for regular residential buildings and open spaces, our film could potentially lower the temperature by about 4 ºC at midday, significantly reducing cooling energy consumption.