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Experimental investigation and numerical modelling of a test box for Radiative Cooling materials testing

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1. Introduction

Radiative Cooling (RC) has emerged as a promising technology for **passive cooling applications**, offering a sustainable and energy-efficient solution to alleviate the increasing demand for air conditioning application. RC technology takes advantage the **earth's natural heat radiation to cool** surfaces without any electricity supply by emitting thermal radiation to the **outer space** by using the **transparent window**. For this, high reflective materials in the solar spectrum and high emissive material in the transparent window are required.

2. Radiative cooling technology

RC technology is capable of **producing cold** during the **night** as well in the **daytime** (fig. 1). For **Daytime Radiative cooling (DRC)** special designed materials are required. So, materials with **high reflectivity in the solar** spectrum (0.3 μm - 2.5 μm) and **high emissivity** in the **transparent IR window** (8 μm -13 μm) are required. For this, several materials are tested and analysed under real climatic conditions to show which materials are suitable for this technology.

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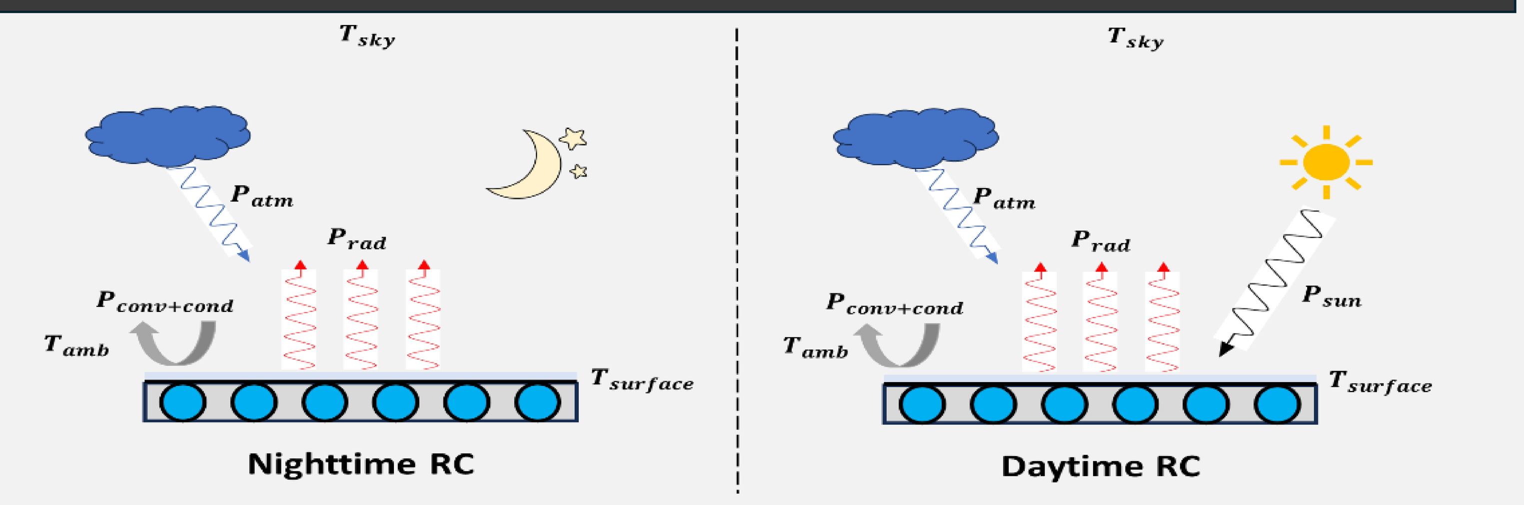

Figure 1: energy balance at a surface resulting in RC

3. Experimental set-up & Numerical model

The experimental set-up used in this study is a parallelepiped wooden box used as a structure filled with **low thermal conductivity polystyrene foam**. And the lateral walls of the test box are covered by an **aluminium foil to reflect the maximum amount of solar radiation** incoming the test box. Also, a **polyethylene film with high transmissivity** in the infrared range is used to decreases the parasitic heat. A sample made from copper substrate and **CHILLSKYN^{TM}**

is used as radiative cooling material. Figure 2.a shows a schematic diagram of the test box and the dimensions of the wooden box. A numerical model of the test box is also developed using finite element method(Figure 2.b).

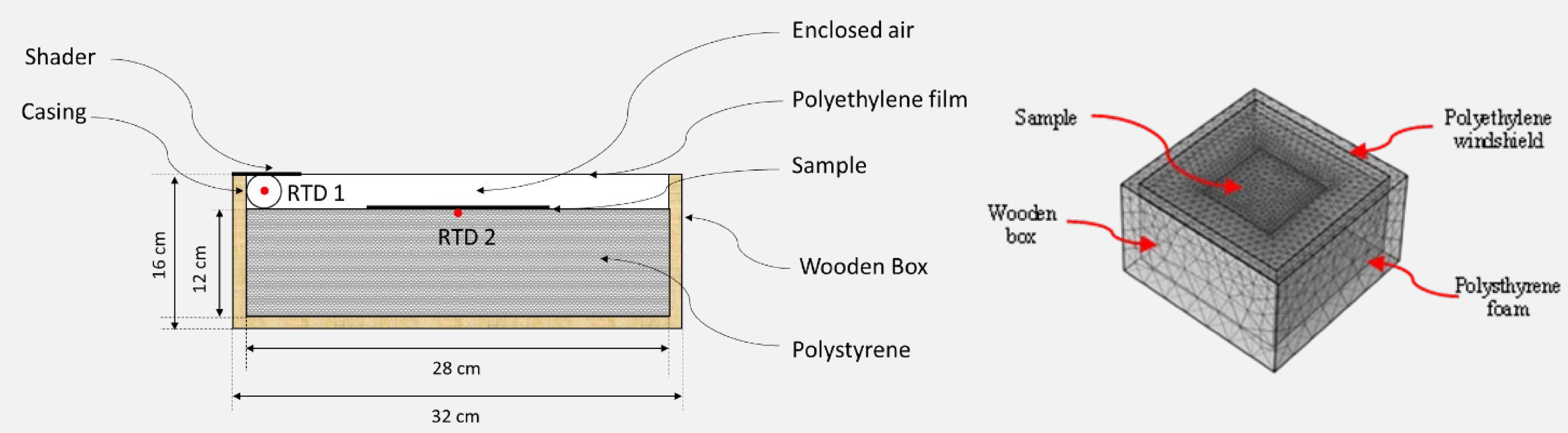

Figure 2: schematic diagram of the test box (left), and the mesh used in the numerical model (right)

5. Results

Figure 3 shows the temperature evolution on the experimental results **During the night, a sub-ambient temperature of about 10 °C is obtained**. Meanwhile, during the day, and as the solar irradiation increases, the temperature of the sample increases also. It is observed that the temperature of the sample of **copper substrate is always under ambient temperature** even at the peak values of the solar irradiation, **with a sub-ambient temperature of 0.3 °C**.

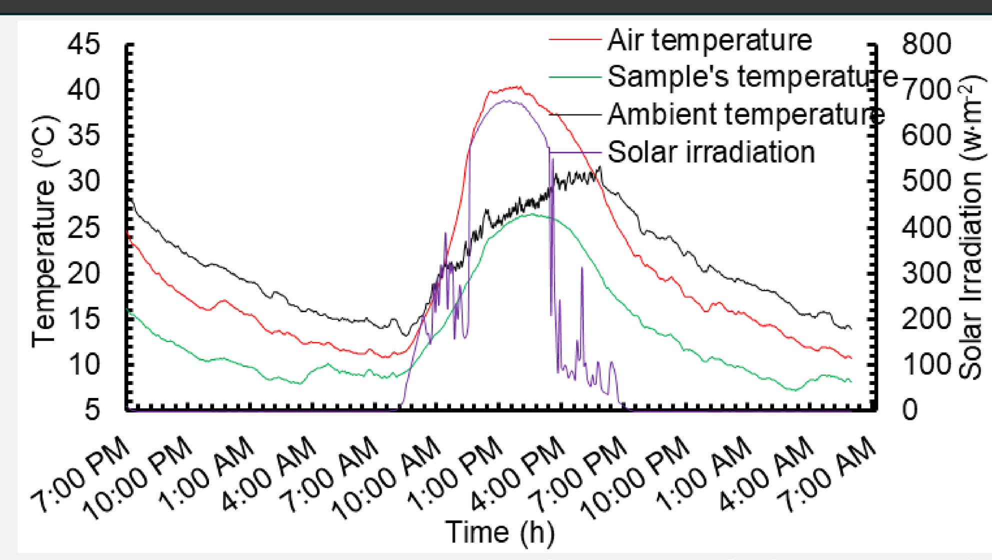

Figure 3: temperature evolution of the sample

The comparison of the sample's temperature of the numerical model and the results obtained from the experimental test is shown in figure 4 (left). The results of the numerical model are compared for **Nighttime Radiative Cooling (NRC) period**.

The **impact of the substrate material** on the thermal behaviour of the radiative cooling is also investigated. 3 types of substrates materials are taken into account **(Copper, Aluminium and Stainless-steel)**, The substrate thickness is also investigated numerically, and, in this case, the cooper is chosen as a substrate with different thicknesses **(0.5, 1, 2, 5 and 10 mm)**.

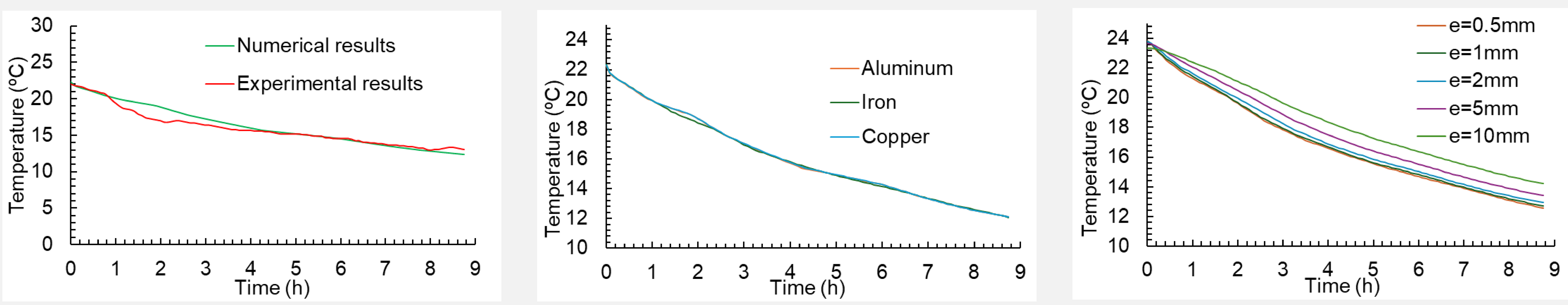

Figure 4: comparison of the numerical model (left), impact of the substrate material (middle), and impact of the substrate thickness (right)

6. Conclusions

- The tested DRC materials reaches sub-ambient temperatures, even during sunny hours.
- The numerical model shows a good agreement with the experimental data for nighttime radiative cooling.
- The substrate material has no impact on the NRC
- Substrate thickness has a great impact on the temperature of the sample, so, thinner substrates reaches lowest temperature.

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