Energy Efficient Vacuum Glazed Window: A System Design and Investigations on Hermetic Sealing Materials

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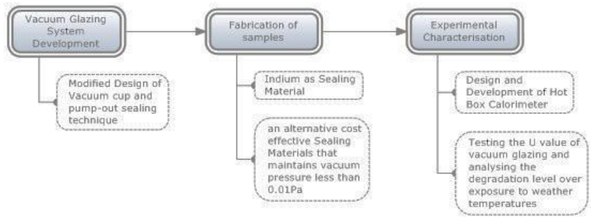
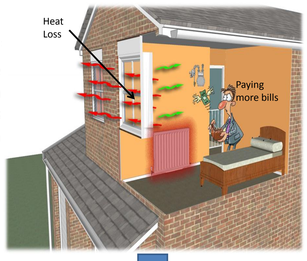
1.Abstract

Predictions by Fang *et al* (2010) indicate that triple vacuum glazing can theoretically achieve a centre of pane thermal transmittance of less than 0.26 W/(m^2.K). To date two materials indium and solder glass have been used for sealing the edges the glass sheets in a vacuum glazing. Indium is a low temperature sealing material (157°C) but is very expensive. Solder glass is a high temperature sealing material (around 450° C). One of the main hindrance to the manufacture of vacuum glazing at the industrial level is the cost. In this poster presentation, a vacuum glazing system for production at a laboratory scale using a modified evacuation pump-out sealing technique is presented. A number of samples have been fabricated using existing and new sealing materials that achieve a vacuum pressure less than 0.001Pa in the cavity of the vacuum glazing samples. An experimental performance verification of samples using new cost effective sealing materials will be executed in a hot box calorimeter to measure thermal transmittance performance of the samples. Issues associated with degradation of the vacuum pressure inside the cavity can be addressed by introducing non-evaporable getters.

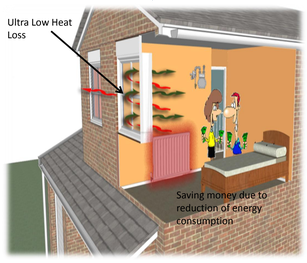
2.Research Context



Heat loss through the windows of dwellings is a major concern due to the increase in use of natural gas in domestic boilers that not only increases the gas utility bills but also emits carbon dioxide that is a greenhouse gas.

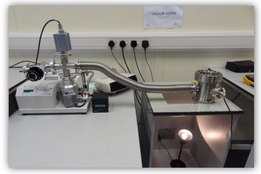


Triple vacuum glazing has a predicted centre-of-pane U value down to 0.26W/(m^2.K) (Fang *et al*, 2010) with 0.44 W/(m^2.K) achieved to date (Arya *et al*,2012) which is approaching the value for external cavity walls. Vacuum glazing can not only reduce gas bills and carbon dioxide emissions but allows an increase in the window to wall area ratio that permits an increase in day light transmittance and solar gains.



3.Vacuum Glazing Production Facility

- A laboratory was established at CREST, Loughborough University, for the fabrication of vacuum glazing. The vacuum system has the capability to reach a pressure of 1x10^{-6}Pa.
- It includes a material testing/design, support pillar placing, glass sheet cleaning and the use of heating system for the fabrication of glazings using different edge sealing materials, as illustrated in figure 1.
- High and low temperature hermetic sealing materials were prepared and tested to understand the sealing properties and achievable cavity vacuum pressure.
- A new approach that includes the use of low cost sealing materials is under development.

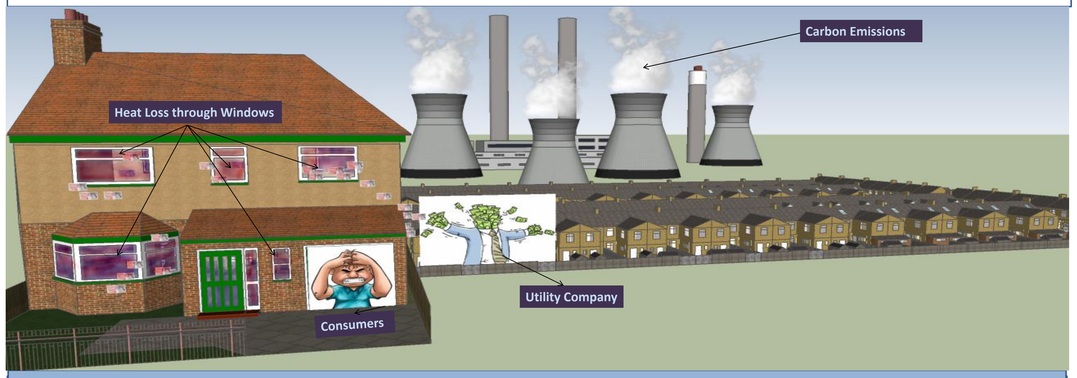

Vacuum system


Materials design/testing section


Glass Sheets and cleaning section


Support Pillar placing section

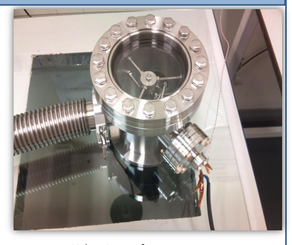
Figure 1: Vacuum glazing production facility illustrations

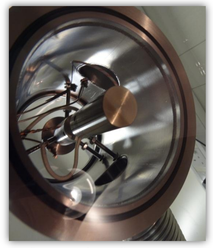


4.Evacuation Pump-out System Design

- A new vacuum cup was designed and constructed with dimensions of 100mm diameter and 150mm height. A pump-out sealing procedure, as illustrated in figure 2, requires a circular glass disc (18mm) or square cover slip (around 10x10mm) pre-soldered with indium or alternative sealing material to be placed over pump-out hole.
- The heating element, cartridge heater and thermocouple mounted a metallic rod controlled through a supporting Y shaped block provides up and down motion of up to 10mm.
- A K type thermocouple fixed to the heating block measures the approximate glass disc/square temperature. Heat transfer at high vacuum occurs through both radiation and conduction due to the contact of the heating block with the glass disc.
- The required temperature is approximately 40˚C more than the melting temperature of the pump-out sealing material to seal the pump-out hole.


Heating Element with supporting block


Side view of vacuum cup


Bottom view of vacuum cup


Top view of vacuum cup

Fig 2: Modified Design of the Vacuum cup and pump-out sealing technique.

5. Results & Discussion

A number of samples have been fabricated with alternative low cost sealing materials that could reduce the cost of vacuum glazing. The two existing materials used by Ulster University and Sydney University groups for the fabrication of vacuum glazing edge seal are either too expensive, such as indium, or high temperature sealing, that limits the use of low emittance coatings such as solder glass.

A cost effective sample of the vacuum glazing using glass metallic fusion sealing material, as shown in figure 3, has been fabricated, further investigation and experimental validation is required, at laboratory scale under rough environment where the best vacuum pressure recorded was 0.0271Pa. This pressure can be reduced by modifying the pump out mechanism with new heating techniques.

Figure 3: A cost effective Glass/Metallic sealing material for the fabrication of vacuum glazing

Indium has also been used to fabricate a 0.3mx0.3m sample of triple vacuum glazing as shown in figure 4.

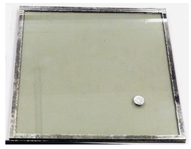


Figure 4: 0.3mx0.3m sample of Triple vacuum glazing using indium as sealing material

A new low cost metallic material has recently been tested in the laboratory and a cavity vacuum pressure of 0.001Pa achieved, the sample shown in the figure 5, is currently under investigation to determine the durability of the seal achieved.

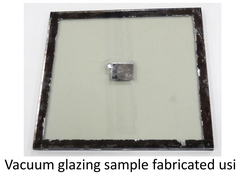


Figure 5: Vacuum glazing sample fabricated using new sealing material

6. Conclusions & Recommendations

- A vacuum glazing lab production facility was developed at Loughborough University for the fabrication of vacuum glazing using high and low temperature sealing materials.
- A pump-out sealing system was designed that achieves good seals.
- A new low cost sealing materials were identified/developed and a pressure down to 0.0271 to 0.001Pa achieved.
- An experimental verification of the new low cost vacuum sealing material is planned in the next few months with samples tested in an hot box calorimeter to determine their thermal transmittance. Issues of the degradation of the vacuum pressure inside the cavity with time can be addressed by introducing non-evaporable getters.

6.Acknowledgement

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7. References

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2. Arya, F., Fang, Y., and Hyde, T. 2012. Fabrication and characterization of triple vacuum glazing at low temperature using an indium based seal. The Energy & Materials Research Conference-EMR2012, Spain.