Fabrication of Energy Efficient Vacuum Glazing using a Novel Edge Sealing Material

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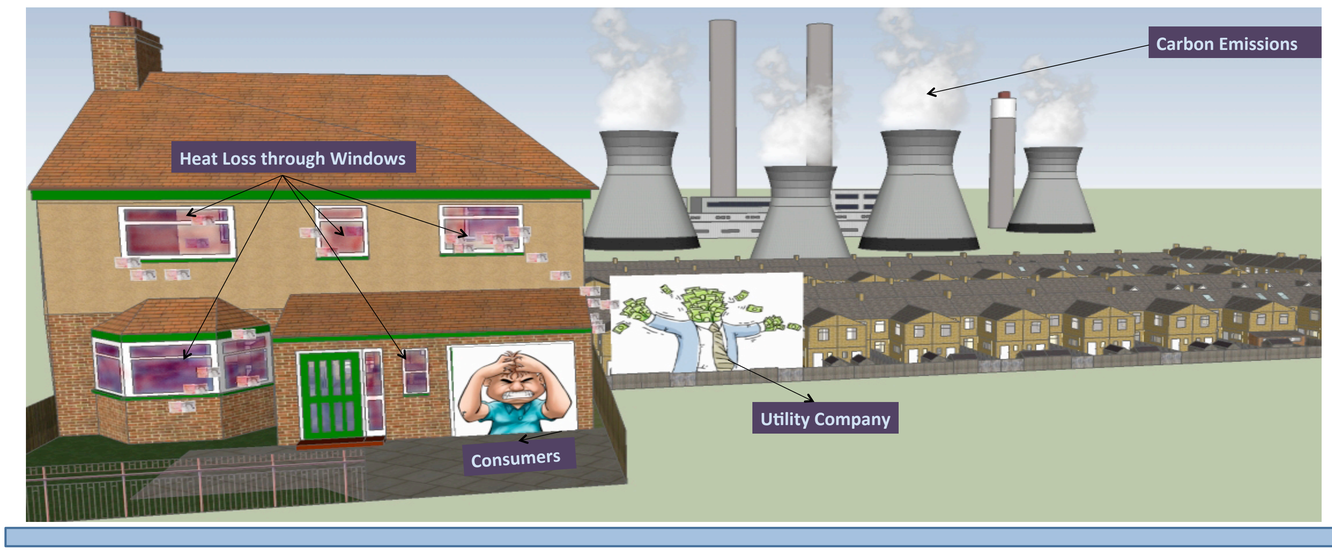
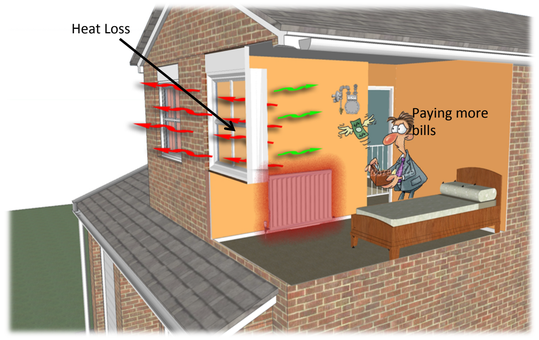
Overview of Research

A Big Picture



Problem



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 CO_2 that is a greenhouse gas.

Solution

Vacuum glazing can not only reduce gas bills and CO_2 emissions but allows an increase in the window to wall area ratio that permits an increase in day light transmittance and solar gains.

1. Abstract

This poster aims at presenting an experimental investigations for the fabrication of vacuum glazing using a novel low-temperature edge sealing material, melts at around 200°C, as shown in figure 1. To date two materials indium and solder glass have been used for sealing the edges of the glass sheets in a vacuum glazing. Indium is a low temperature sealing material, melts at 157°C, but is very expensive. Solder glass is a high temperature sealing material, melts at around 450°C, but has limitation of using low-e coatings and a tempered glass. 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 a novel cost effective edge sealing material that achieves an evacuation pressure less than 0.046Pa 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.

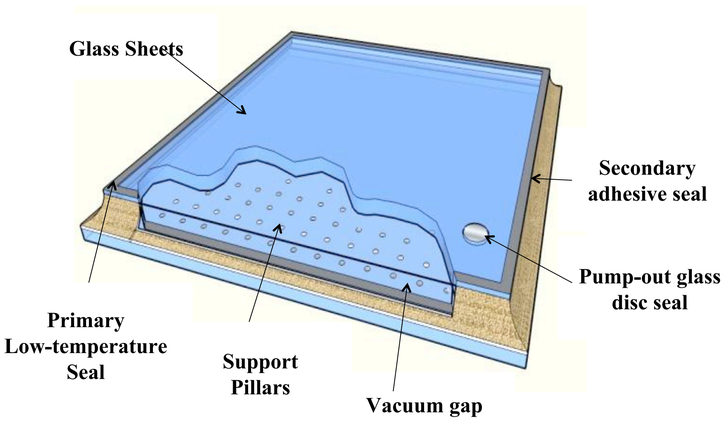
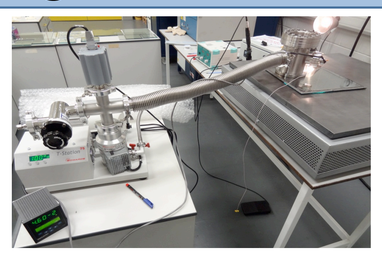


Figure 1: Graphical representation of the vacuum glazing using a novel sealing material

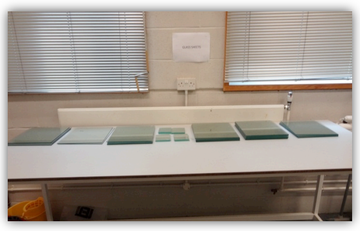
2. Vacuum Glazing Production Facility

- A laboratory was established at CREST, Loughborough University, for the fabrication of vacuum glazing. The vacuum system has the capability to reach to a pressure of up to $1x10^{-6}$Pa.
- It includes a material testing/design, support pillar placing, glass sheet cleaning and the heating system for the fabrication of glazings using different edge sealing materials, as illustrated in figure 2.
- 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



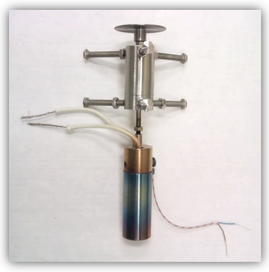
Glass Sheets and cleaning section

Support Pillar placing section

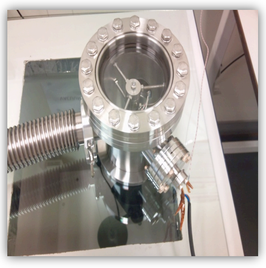
Figure 2: Vacuum glazing production facility illustrations

3. Evacuation Pump-out System

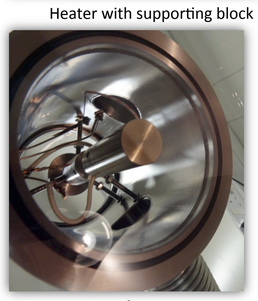
- A new vacuum cup was designed and constructed with dimensions of 100mm diameter and 150mm height ,as shown in fig 3. A pump-out sealing a square cover slip (around 10x10mm) pre-soldered with a novel sealing material to be placed over pump-out hole.
- The heating element, cartridge heater and thermocouple 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/ square.
- The required temperature is approximately 40˚C more than the melting temperature of the pump-out sealing material to seal the pump-out hole.



Heater with supporting block



Side view of vacuum cup



Bottom view of vacuum cup

Top view of vacuum cup

Figure 3: Modified Design of the Vacuum cup and pump-out sealing technique.

4. Fabrication Process

Preparing glass Sheets
- Drill a pump-out hole on the upper glass sheet.
- Clean the glass sheets with water, isopropanol and acetone.
- Bake the glass sheets to 200°C for up to 2 hours.

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Applying Edge Sealing Material
- Solder the sealing material around the periphery of glass sheets.
- Preparation of same material gasket square wire loop.

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Placing Support Pillars
- Support pillars positioned on lower glass sheet
- Upper glass sheet situated on the pillars

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Heating the sample in the Heating Oven
- A sealing temperature was less than 200°C

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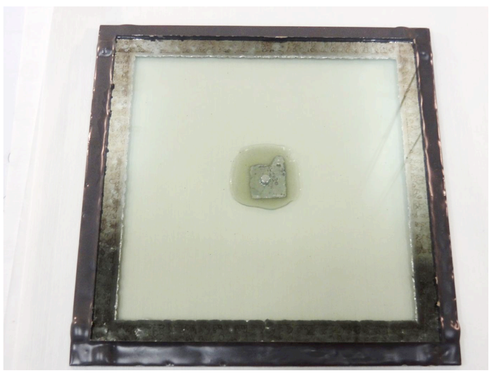
Evacuation & pump-out hole sealing
- When the sample reached 120°C in the heating oven, the sample was taken out and placed on the hot plate surface in order to maintain the temperature and evacuate the sample.
- Seal the pump-out hole using glass square/disc soldered on one side with same sealing material.

Figure 4. A block diagram of the fabrication process for the development of vacuum glazing

5. Results & Discussion

A number of samples have been fabricated using a novel cost effective sealing material that could reduce the cost of vacuum glazing at an industrial production level. The two existing materials used by Ulster University and Sydney University groups for the fabrication of vacuum glazing; their edge seals are either too expensive, such as indium, or require high temperature for sealing, such as solder glass, that limits the use of low emittance coatings and tempered glass. This novel material with applied innovative techniques for the fabrication of vacuum glazing at around 200°C. In this on-going investigative research work, two samples are presented. sample A-170mmx170mm, shown in Fig. 5a, achieved a vacuum pressure less than 0.001Pa. Due to its small size, the level of stresses on the periphery of the sample was low. This experiment was repeated and it was found that similar vacuum pressure was achieved. Sample B-300mmx300mm, shown in Fig. 5b, achieved a vacuum pressure of up to 0.046 Pa and the level of stress patterns over pillars in between glass sheets were observed after pump-out sealing.



Sample A

Sample B

Figure 5a, Sample A, vacuum glazing 170mmx170mm achieved a pump-out pressure of less than 0.001 Pa.
Figure 5b, Sample B, vacuum glazing 300mmx300mm achieved a pump-out pressure of up to 0.046 Pa.

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.
- Vacuum glazing samples were successfully fabricated using a novel low-cost sealing materials that achieved an evacuated pressure down to 0.046 Pa.
- 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.

7. Acknowledgement

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