Energy Harvesting from Sunlight in Window Panes

P. H. Eller, and T. Østergaard

DTU Nanotech, Technical University of Denmark

Patterned nanostructures can be implemented in windows to reduce the amount of heating in buildings due to sunlight, and thereby reducing the energy required for air conditioning. IR-light is solely a source of heating, and so instead of using energy to cool overheated rooms due in part to IR-light, it would be advantageous to harvest the energy in the IR-light. Many other designs are already addressing the idea of reducing heating of rooms due to sunlight by adding functionality to windows, such as adding anti-reflective coatings to reflect all non-visible light. But it would be smarter to use the sunlight instead of just reflecting it. With this in mind transparent solar cells have been demonstrated, but with lifespan much lower than the lifetime of windows. This project explores the idea of an intelligent window utilizing a smart pattern of grating couplers to redirect IR-light from incident solar light. A grating coupler is a simple 2D grating structure on a guiding layer which is designed to couple incident light of specific wavelength into the plane of the guiding layer. By imprinting grating couplers and wave guides onto window surfaces, it is possible to partially redirect IR-light from incident sun light. This does not only reduce heating and need for air conditioning, but also harvests the light by guiding the coupled light to solar panels at the sides of the window panes. The solar panels would also be efficiently used since guiding the light increases the intensity, by confining it spatially in a small waveguide. A grating coupler structure is quite durable under proper isolation, and is a potential alternate solution to the issue of light control in rooms. A disadvantage though is that the design is quite rigid. The coupling efficiency is highly dependent on the angle of incidence of the light, and therefore the position of the sun. Unless this could be accounted for, the grating couplers would only be 'active' a few hours a day. So reconfigurability with regards to the coupling angle would be a major improvement. Having a layer of liquid crystals could be the answer to achieving reconfigurability, since liquid crystals have a refractive index which is tunable by an applied voltage. The coupling angle is determined, among other parameters, by the refractive indices of the different material layers in the grating coupler structure and therefore liquid crystals could be used to optimize the coupling angle with regards to the position of the sun. Employing liquid crystals could also enable an on/off function, switching the coupling off in wintertime. One could imagine an automatically optimized thermally actuated (intelligent) system that activates when the sunlight has a threshold intensity, and then regulates the coupling angle to always maximize the redirection of IR-light. Further benefits of grating coupler systems designed for IR-light are that such systems are mass producible micrometer sized structures. A large scale production should be possible using different parallel production techniques such as UV lithography or nano imprint lithography and other well known techniques. With these techniques waste is greatly reduces while simultaneously being treated properly and not being spilled to the environment as hazardous material. One advantage is also the possibility to construct self-contained or closed systems, with the window as the power source. The system could include electrical devices such as air conditioning systems or an energy storage unit. A closed system would allow an easy installation in everyday homes. It might even be possible to connect the window to the electric grid of the house and have energy production to the household. Every year 11 billion dollars are used for air conditioning alone in the USA, and this corresponds to about 100 million tons of carbon dioxide emissions each year. Thus there is plenty of room for new and innovative solutions, which could be turning windows into heat controlling, energy saving and energy generating devices by implementing grating couplers in them.