ENERGY CONSERVATION THROUGH VACUUM COATINGS

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ABSTRACT

The United States and other industrialized nations are faced with the unprecedented challenge of providing energy services to an expanding economy in a manner which is environmentally and economically sound. Since the energy crisis of 1973, energy efficiency has emerged as the most effective manner to reduce dependencies on foreign oil imports, minimize emissions which contribute to global warming and ozone depletion, and stimulate local economies. Between 1973 and 1986 the United States economy grew by 35% without any net growth in energy supply. Energy efficiency improvements made most of this possible. To continue with this trend will require a significant redesign of many traditional consumer goods. Buildings, automobiles, and appliances must be redesigned for increased energy efficiency and user satisfaction. This paper discusses how current and future applications of vacuum coating technologies can play a significant role in developing many of these new energy efficient consumer goods.

The most striking current example of how vacuum coating technologies have contributed to energy efficiency is in the area of low-emissivity (low-E) coating technology. During the mid 1970's, window researchers realized that the predominant form of heat transfer through a double glazed window subjected to a cold exterior environment was by infrared radiation from one glazing layer to another; the warm interior glazing layer would radiate heat to the colder exterior glazing layer. The best way to stop this heat loss would be through a (visibly transparent) low-emissivity or infrared reflecting coating applied to one of the glazing layer's surfaces. Research initially sponsored by the Department of Energy and commercialized by the private sector led to the introduction of the first commercially available low-E coatings in 1982. Since then, this technology has expanded dramatically to the point where over 30% of all new residential windows in 1990 used low-E coatings and where most major window manufacturers offer them as a standard product or option. Without the widespread use of low-E coatings, other improvements to energy-efficient windows such as low-conductivity gas-fills and insulating frames would not have been useful. Today's low-E gas-filled window looses about half as much energy as a conventional double glazed window manufactured 10 years ago. By the year 2000, further advances in low-E and energy efficient window technologies are expected to halve this number again. Such technological improvements are expected to greatly reduce the energy use attributed to window products; in the United States today this is estimated at 5% of the total energy use or the equivalent output of the Alaska pipeline.

While the first generation low-E coatings were intended to minimize infrared radiant heat transfer from a warm interior to a cold exterior, window researchers soon realized that the same vacuum deposition processes used to make infrared reflecting coatings could be used to manufacture coatings which selectively filtered out unwanted portions of the solar spectrum. In many windows in cooling dominated buildings (i.e. residences in the sun-belt and commercial buildings throughout most of the United States) and in automobiles, cooling loads from solar gains are a significant fraction of overall cooling requirements. Traditionally, this need was met through the use of tinted or reflective glazings which blocked both the visible and solar infrared portions of the solar spectrum. Spectrally selective low-E coatings were developed to transmit most of the visible portion of the solar spectrum but to reflect almost all the solar-infrared (heat) portion of the solar spectrum. The results are glazing systems which appear clear to the human eye but which have the solar heat gain impacts of typical tinted or reflective glazings. The transmitted daylight allows electric lights indoors to be dimmed or even turned off, thus increasing energy savings. Presently, spectrally selective glazings must be protected by being placed on a glazing surface facing the inside of a sealed double glazed unit. Future applications include the single glazed durable spectrally selective coatings, available preferably directly on glass, or alternatively as a "glue-on" coated plastic film.

Current research activities around the globe are focusing on the development of multi-layer vacuum deposited coatings designed to have dynamic switching solar optical properties controlled by either temperature (thermochromic), incident solar radiation (photochromic), of by an electric current (electrochromic). Such switchable glazings will offer the building occupant or building energy control system the ultimate control in window energy flows.

The success of low-E coating and low-conductivity gas-filling technologies for windows has led LBL researchers to adapt such technologies to the development of high performance insulation systems. Prototype insulating materials built using polyester films vacuum coated with a thin layer of aluminum have been tested at R-values of 13 hr-ft^2-F/Btu (3.5 times that of fiberglass and almost 2 times that of the best CFC blown foams). Such insulations will help make the next generation of refrigerator/freezers and building walls more energy efficient.

Electric lighting accounts for about 25% of all electricity use in the United States. Infrared reflecting coatings have been used in new lamps and other high performance coatings have been developed for lighting fixtures to improve their efficiency. Several new light bulbs utilize infrared reflecting coatings on the bulbs' inside surface to reflect heat back to the filament (thereby increasing its temperature and efficiency) while allowing visible wavelengths to pass through. Other vacuum deposited coatings are now placed behind fluorescent fixtures to reflect higher fractions of visible light down to the work plane.

The effectiveness of technological advances in energy efficient products is being increased by a new interest in energy efficiency among many gas and electric utilities throughout the United States. Utilities and their state regulators are realizing that the primary objectives of utilities ought to be to provide energy services (i.e. keeping homes comfortable) at the lowest overall cost not just to provide more energy supplies. Many utilities are being actively encouraged to invest (and make a profit) in conservation in a manner analogous to investments in new power plants. The result is a a huge new source of capital for energy efficiency investments. Furthermore, utilities are interested in investments with longer term paybacks than the typical consumer; an energy efficient window with a ten year payback and a lifetime of twenty years is a great investment for a utility even though it may not seem as compelling to first-time homeowners.

Sophisticated, but cost-effective, means for controlling light and heat will continue to play an important role in meeting the energy efficiency challenges of the 1990s. Vacuum deposited thin film coatings have played an important and growing role in the efficiency gains of the last fifteen years and have the potential to continue to do so in the next decade.

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