

# Soft Façade: Steps into the Definition of a Responsive ETFE Façade for High-rise Buildings

## Work in Progress

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*Façade systems are to a great extent responsible for both the energy-performance and overall aesthetic qualities of a building. The study presented in this paper explores the tectonic integration of a distributed computer network and the façade of a high-rise tower through the use of ETFE cushions, exploiting the soft nature of this material to embed a sensor network to provide touch-responsive changes of opacity in the façade, potentially improving the energy-efficiency of a building, and promoting a novel kind of dialogue between a space and its inhabitants.*

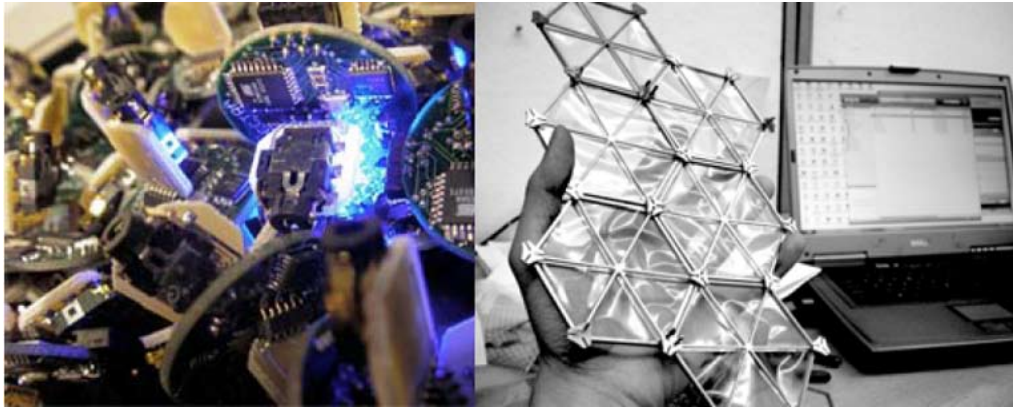
*We propose that the inclusion of computer networks and displays in the built environment necessarily leads to new design philosophies that solve tectonically the dialogue between traditional materials and technological devices, and we put forward the first results of a research into a novel implementation of electrochromic ‘smart’ cushions that allows for changing opacities of the façade elements of a building in response to human touch.*

**Keywords.** *Responsiveness: smart windows; interactive architecture; tangible interfaces*

## Introduction

In recent years, architectural thinking has been concerned with the pervasive presence of electronic devices and information networks as important constituents of urban space; this concern has led many architects to see the overlaying of digital technologies on buildings as a relevant design problem, and therefore some have started to seek a deeper understanding of these technologies in order to integrate them

to the architectural practice. Relatively recent works of architecture by contemporary architects like Prada Store by Rem Koolhaas, Jumpcuts by Diller+Scofidio and NYSE Floor by Asymptote Architecture strive for an aesthetic integration of electronic networks and displays with traditional architectural materials in their buildings. This study provides a schematic proposal for merging tectonically ETFE cushions and electrochromic foils through sensor technologies in a novel type of touch-responsive architectural façade.



*Figure 1  
A Micro Controller by Vincent  
LeClerc and an early scaled  
prototype of the proposed  
façade*

Façade systems play a determinant role in the energy-efficiency of a building. A traditional architectural element such as the brise-soleil is present in works from Le-Corbusier's Citroen House to Renzo Piano's New York Times Headquarters. The proposal presented in this document explores the notion of an active and touch-responsive brise-soleil or shading system for a building. We discuss and pose two questions: a) Can a brise-soleil be reinterpreted by means of new materials and computer networks? And b) Can we design a tactile, responsive façade that changes its properties according to the desire of the users of the space?

In this paper we posit a response to these questions by merging three recently available technologies into a new tectonic system for a curtain wall tower façade. These three technologies are as follows: (1) architecture-grade ethylenetetrafluoroethulene (ETFE) cushions, (2) electrochromic film "smart windows," and (3) low-voltage, high sensitivity pressure sensors linked to a network of micro controllers.

The paper will provide a short overview of the three technologies involved, information about a series of scaled prototypes, and a schematic proposal for the implementation of the system in a full-scale prototype. The final section examines the results and problems found, and suggests some discussion points on the potentials and limitations of the

system. We propose that the inclusion of computer networks and displays in the built environment necessarily leads to new design philosophies that solve tectonically the dialogue between traditional materials and computer networks.

## **Merged technologies**

### **ETFE foil cushions**

Ethylenetetrafluoroethulene (ETFE) cushions can be most simply described as two thin sheets of a very strong and clear polymer, welded at their perimeters such that the space between the two sheets can be filled with air.

ETFE cushions have been largely used by architects since the 1980s as an alternative to glass because of their similar transparency, higher thermal isolation properties, and energy and cost-efficient assembly and production processes; ETFE cushions are usually inflated at 250–400 Pa with a small pump and topped up intermittently (Robinson-Gayle 2001). This same study has found ETFE to compare advantageously to glass in several aspects: 1) The energy required for its production is over ten times less per square meter of coverage than that of glass, primarily due to relatively low necessary heat and gaseous by-products and 2) ETFE cushions provide greater luminosity: the cushions allow an equal

range of light frequency transmission (translating into color visibility and fidelity) and greater total visible light transmission. This is the reason why the use of ETFE cushions in architecture has been successful in large roofs and atria. Its high degree of sound transmittance however poses a problem for its use in inhabitable spaces. For a comparative analysis of ETFE and glass glazing systems, refer to (Robinson-Gayle 2001).

Recent examples such as the 2001 Grimshaw's Eden Project in England and the 2003 Masoala Rain Forest in Switzerland designed by Gautschi Storrer, offer a promising look into the expansion of ETFE foil cushion use on facades.

### “Smart windows”

Electrochromic windows, also called “smart windows”, change their optical properties (transmittance and reflection) in a reversible manner when voltage is applied and current flows through them (Heusing 2005). The material responsible for transmitting this charge needs to have thermochromic or electrochromic properties, that is, sensible to temperature or electrical charge variations (Lamper and Granqvist 1990). Most of the smart windows rely on a thin layer of electrochromic material, generally composed of the oxides of certain metals. The change of opacity is given by applying a small electric charge (5.0 Volts) that reverses the shuttling of charge ions between the electrochromic thin film and a transparent conductor (Granqvist 1998).

This technology has different applications because of the visual variations it provides, and its energy-efficiency: studies show that by adopting “smart window” energy control strategies in a building 170 kWh/m<sup>2</sup> in energy can be saved annually (Granqvist 2005). For a full case-study of the application of Smart Window technology as a remedy for solar gain in a building refer to (James 2004). Also, flexible electrochromic foils have the potential to be produced industrially (roll-to roll technology) thus making this technology more accessible to the construction market (Granqvist 2005).

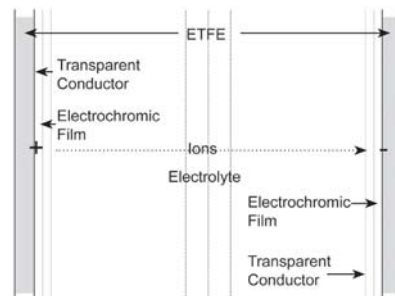
Although most of the applications of electrochromic materials are on flat glass surfaces, some recent explorations have been applying this thin film to curved surfaces, specifically to motorcycle helmet's visors and windshields of cars. These advances on the flexibilization of electrochromic materials show how quickly the technology is advancing towards a totally malleable electrochromic surface with sufficient optical modulation range, dynamics, and durability (Granqvist 2005). Although the phenomenon of mechanical deformation has not yet been thoroughly studied in electrochromic foils, the Swedish team led by Prof. Granqvist has found that these foils do admit certain degree of mechanical deformation without deteriorating. These are reasons to believe that the vision of a “smart cushion” is within the margins of the existent technology.

### Pressure sensors

Sensors are devices that respond to different types of stimuli by returning a differential voltage output. Many types of sensors are commercially available and their potential to trigger new ways of interaction between people and architectural space is just starting to be explored (Manovich 2000). Sensors usually work in connection with a microcomputer that averages, calibrates, and processes the input of a potentially large number of sensors.

Pressure sensors use elements such as plates, shells, and tubes that deflect when pressure is applied. This way the sensor translates pressure to a

Figure 2  
A scheme of an electrochromic device



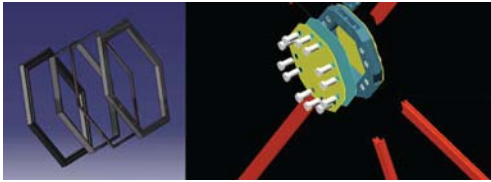


Figure 3  
Early approaches to an integrated smart cushion

physical movement that can be detected, measured, and transduced to obtain an electrical or other output (Bicking 1998). Pressure sensors are widely used in industrial applications such as remote indicators of fluid levels in tanks and for detecting leaks in evaporative purge systems in automotive engines (Bicking 1998). Space pressure sensors are common in space and marine vehicles, as well as in medical

applications. In architecture pressure measurement methods have been used to study the effect of a ventilation system of a building in an urban area (Nobuyoshi and Takeshi 1985).

The Motorola MPX series is a family of sensors that measures pressure by means of a thin silicon diaphragm and is suitable for interfacing with a micro-controller. Its sensibility range (from 0 to 50 KPa) exceeds the expected range of pressures inside a cushion (from 0.4 Pa to 2 KPa) and its full-scale output (5.0 Volts) is relative to the range. The role of the micro-controller is to calibrate the output of the sensor to the range required by the electrochromic foil of the cushion. For the purposes of the prototype we chose the MPX5050 case 867-08.

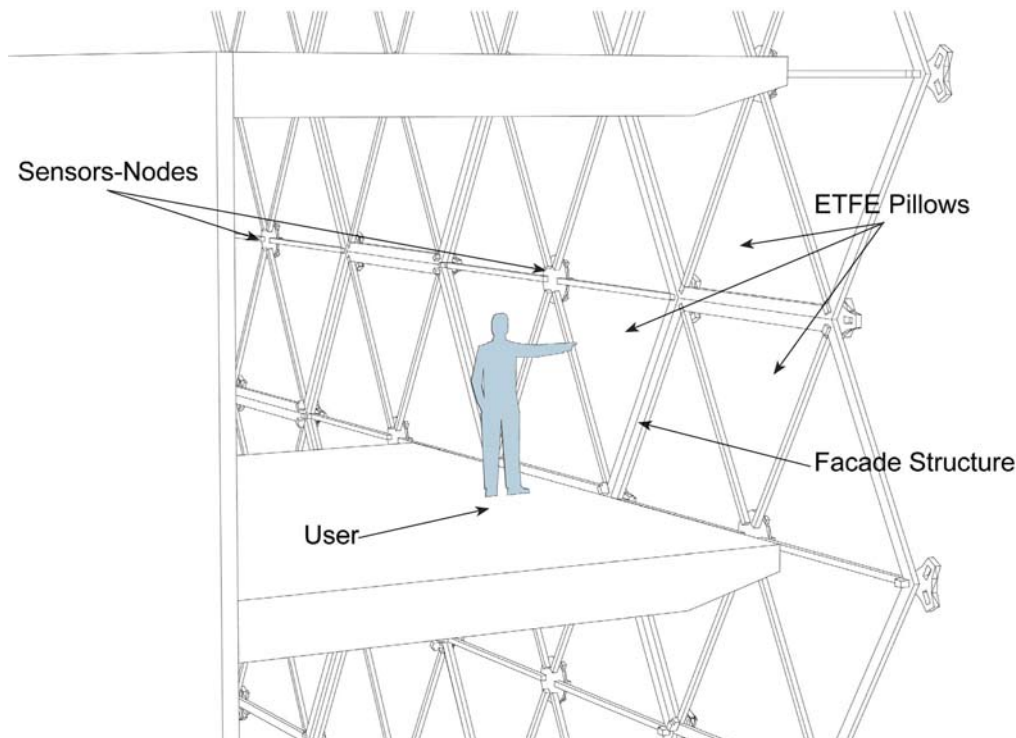
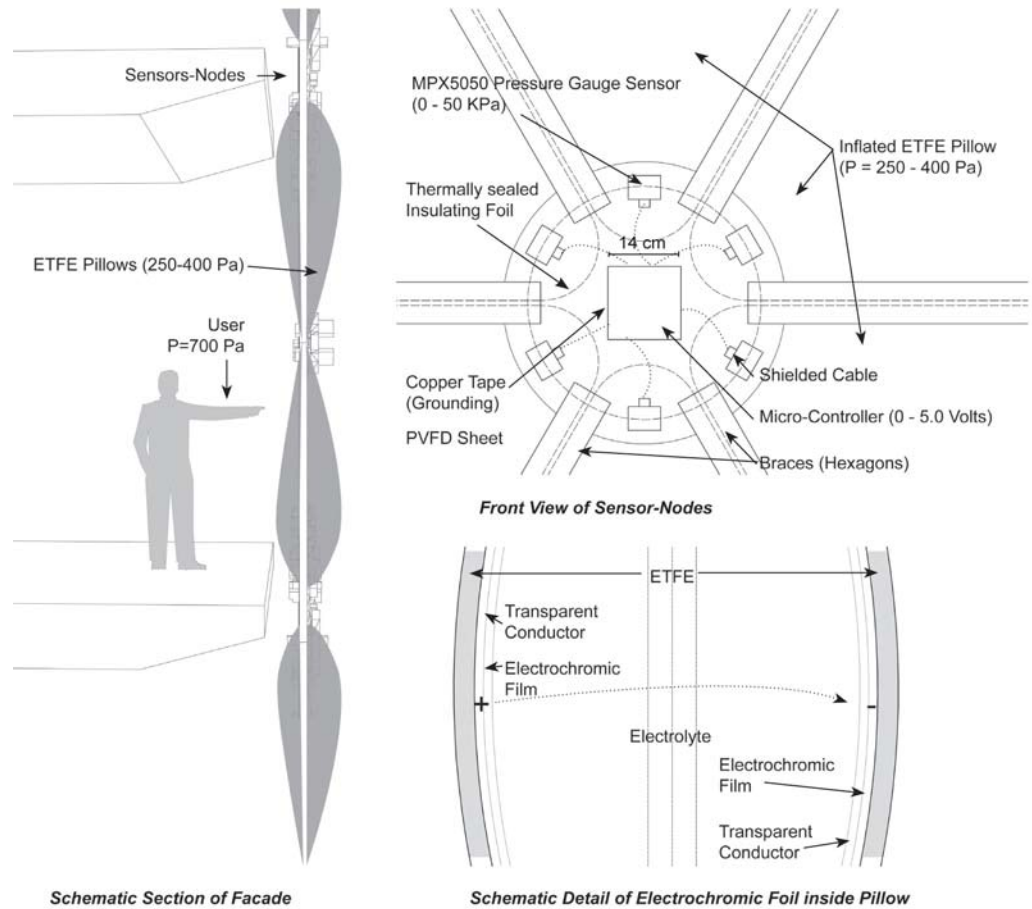


Figure 4  
The main components of the proposal

Figure 5  
Schematic section of the facade, detail and front view of a sensor's node



### A touch-responsive electrochromic ETFE foil cushion

In this section we will discuss a system that integrates the Smart Window technology in a full-scale ETFE cushion for a building façade by means of an air-pressure sensor. This section will provide schematic information to build a prototype of a single smart cushion.

- The sensor's node (see Front View) is a disc where a micro-controller receives input from 6 different sensors that detect the changes in the air pressure in the interior of an equal number of ETFE cushions caused by human touch. The pressure sensor (Motorola MPX5050) sends a voltage signal to the micro-controller, which scales and calibrates the charge sent (5.0 Volts for full-

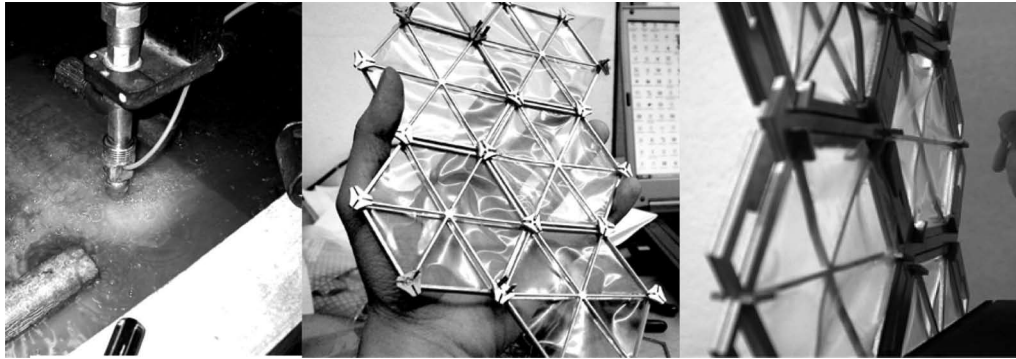


Figure 6  
Scaled prototypes in  
aluminum

scale sensitivity) within the range of pressure sensing (0-50 Kpa) to a range readable by the electrochromic foil. The slight electrical charge reverses the polarity inside the cushion causing the electrochromic foil to change the opacity of the cushion.

## Problems

- The proposed schema for a smart cushion is yet to be tested; the sensor, the kind of interaction, and the architecture in general could prove inadequate at the prototype scale.
- The wind loads in the exterior of the façade would add noise to the signal, especially in a high-rise building, making it very difficult to measure the right stimuli. Possible solutions: a) internal layer of ETFE dividing the interior of the cushion in an interior and exterior chamber. b) Thinking of the person that touches the cushion as a resistor of a circuit that if closed sends the electrical charge (5.0 Volts) to the electrochromic foil of the cushion.

## Next steps

The development of a 1:1 scale prototype of an electrochromic smart cushion that takes advantage of the progresses on flexible thin electrochromic foils.

The objective of this first prototype is to evaluate the feasibility of the integration of these two materials. A second prototype that incorporates distributed networking that senses the air pressure of the neighboring cushions and therefore controls their opacity with gradients could be implemented.

The discussed project is in a very early stage of design and development. Further research and collaboration is needed with the designers and fabricators of the technologies in order to assure absolute inter-compliance. Once completed, the prototype will certainly yield many more problems and questions for future exploration. Finally, within the potential synthesis between local and global behavior of a networked façade, whereby the system does indeed have global, centralized intelligence but is able to be overridden by local demands, lies many opportunities for future exploration. For example, by allowing global, programmed manipulation of a locally controllable opacity, the use of an entire façade as a pixel-graphics evening display becomes possible by manipulating the opacity of each ETFE cushion and thus controlling the external visibility of the internal security lighting in the unoccupied building.

## Contributions

A schematic description of a novel system for a façade that uses ETFE foil cushions as touch-responsive

electrochromic smart windows, and a basic discussion on its convenience and implications.

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