# Malleable Matter and Atmospheric Substance

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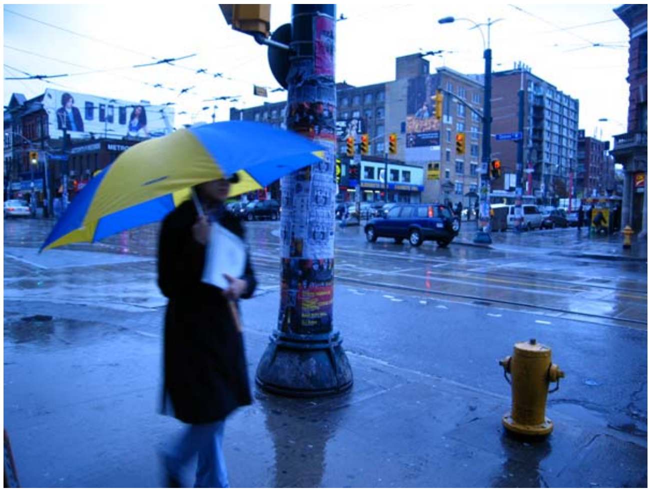

**Figure 1. Spadina Street, A typical streetscape in Toronto.**

## ABSTRACT

This paper will unravel the effects of the variations in atmospheric conditions on the building envelope as a 'creative potential' for architectural intervention through a research/creation project entitled '*Malleable Matter*'. Undertaken as part of a larger investigation of material innovations in architecture, the *Malleable Matter* project explores the potential of textile-based materials as a hybrid art and architectural medium that can bring design, technology and materials' research together in built spaces.

**Author Keywords:** Weather elements, responsive architectural skin.

## INTRODUCTION

As we see in the successful examples of sustainable buildings, the surrounding natural elements and energy resources such as water, sunlight, wind and soil can be integral to the building design and operation. Further, materials research offers a new kind of responsiveness to the environmental conditions. For example buildings or structures that move with wind forces to achieve better material and building performance, well-engineered structures that actively resist earthquakes, and building materials that capture and emit light when needed, or become hydrophilic-water permeable or hydrophobic-water resistant based on the moisture levels are being researched in architecture as well as allied fields (Klassen 2006). This body of work suggests that the embedded or enhanced properties of materials can reveal, harness, transform and release the energy gathered from the weather elements when necessary. As such, the wind, light, rain and snow fall can have an impact on the appearance, luminosity and heating/cooling of building skin. These new materials also offer moments of experience that transcend the distant view of weather into an authentic observation that is perceived by city's inhabitants with passing of time. This in return can enhance our perceptions of the changing weather conditions and make us more aware of the weather patterns in relation to climate change. Thus new materials have the potential to offer both and engineered efficiency and enhanced perceptual awareness to climate change.

**Figure 2. University Avenue, Snow and high-rise building.**

## ARCHITECTURE AND WEATHER CONTEXT

**Figure 3. Rain drops on a glass clad skyscraper.**

The form and language of architecture has changed drastically in the last century, however its primary function, although it has come a long way since mankind started building millennia ago, has not changed much in principal. Architecture provides a 'place' and much desired sealed shelter from the weather elements. Buildings are constructed as static entities and are expected to remain in their original state for decades regardless of the changes in the surrounding natural environment (Figure 1 & 2).

Weather, in most large urban centers we live in, is perceived as more of a nuisance, something that should not affect our busy lives. As inhabitants of Toronto, we seem to notice weather only when there are extreme conditions and calamities. Complaints about snow, or lack of it, slush, freezing rain, heat and humidity, potholes, and brownouts seem insignificant in comparison to the deadly weather reported by media from elsewhere in the world. Climate, as an abstract notion or predictions of its near and distant future while being a source of everyday conversation, complaint, superstition, scientific exploration, as well as media hype, has now become a highly politicized ecological issue in the age of global warming and weather extremes. In particular the popular media issues articles that are inundated with predictions of doomsday messages and hopelessness.

We know a lot about the pattern of transportation, trade and urban development in Toronto but very little about how water, land, air, and climate have affected and will continue to affect further architectural development. The term 'Toronto, originally derived from a Mohawk term 'tkaranto', meaning 'trees standing in the water' shows a connection to the city's lost natural ecology although the current associated meaning as a 'meeting place' speaks more about the its current commercial reality (Wilcox, Palassio & Dovercourt 2007). I find this lost meaning quite poignant about what I am advocating in terms of architecture and its connection to the natural environment it is situated in. How a building will sustain itself over its life span and respond to the elements; the soil, the water, the air, the wind and the sun can be forgotten or ignored (Figure 3).

In large urban centers, global warming or climate change is a distant phenomenon experientially. If weather is the last vestige of nature in the city, will we continue to complain about it more than ever despite our troubling and obvious contribution to its change? If we accept the impact of our urban habitats on the local/global climate, will we still appear reluctant to acknowledge the often silent consequences that the built environments contribute to weather conditions that we live in?

Increasingly at unprecedented rates, built environments rely on mechanical systems and use of energy from fossil fuels to keep functioning at optimal physical condition, temperature and lighting levels. A building's demand for energy begins with the acquisition of material resources, manufacturing, transportation, construction and continues especially for its air handling and lighting requirements during its use and upkeep, as well as its demolition and possible recycling/reuse of materials when possible.

Built environments are responsible for 40-50% of greenhouse emissions and rely on non-renewable energy sources such as coal, oil, natural gas, propane and nuclear power for heating, cooling, ventilation, lighting, and use of equipment and appliances during their life span. By using the discussion of material innovations and their relevance in architecture, this personal investigation is derived from a desire to celebrate and sustain various conditions of the atmosphere and propose a design tool to implement changes in our attitude towards built environments.

Given the context of social and environmental changes we are living with, in my case in Toronto although similar issues can be generalized for much of the world's urban centers, there can be no doubt that architecture has to concern itself with reducing its impact on the natural environment and its energy dependency and not just with form, function, aesthetics and technology. I feel that current architectural debate in Toronto has to be subverted from its focus on much aestheticized mega-cultural infrastructure projects by star architects towards speculations about how we may be building in the near and distant future.

A new way to think about architecture as a 'responsive construct', i.e. buildings that change with time and weather elements rather than a static entity is proposed to take built environments outside the domain of ugly and beautiful and provide a tool to address the bigger climate issues. This suggestion does not imply loosing sight of architecture as a cultural artifact, but rather advocates developing a new language of architecture along with its criticism that deals with the immediate resources of a city without the depletion of the local and global ecology.

By using rather than avoiding the elements of weather such as snow, rain, light, wind, and fog etc. to design with, we can create an architectural practice that is responsive and responsible. This approach can enhance our multi-sensory experiences and make us more aware of weather as a contributing factor to the city life rather than working against our lifestyle. Exploration of architectural issues within this context is hoped to provide an opportunity to re-examine our ideas of shelter and climate, change and permanence and contribute to the debate about the future of architecture in Toronto as well as within the global context.

## A NEW APPROACH TO MATERIALITY IN ARCHITECTURE

**Figure 4. Thermal camera image showing surface temperature of buildings.**

Research shows that developments in materials sciences and transfer of technologies from printing and electronics industries will help us make buildings that better respond to the environmental conditions that they are situated in (Klassen, 2006).

The materials research and developments in architecture can be summarized in two distinct approaches. The first approach emphasizes new materials as something magical; a new material that does everything that is expected from a building skin. For example, SmartWrap™ R&D and prototypes developed by Kieran Timberlake Associates LLP, propose that a material such as PET (polyethylene terephthalate, used for water bottles), could have embedded technologies to provide weather protection, solar control, energy generation, information display and power distribution. SmartWrap™ incorporates emerging technologies in heating, cooling, visual display, lighting, and energy collection onto its surface through a printing process that is similar to that of inkjet printers. KTA suggest that consumers can buy their building skin as an all-in-one package from their local Home Depot Store (Klassen, 2006).

The second approach in materials research emphasizes innovations that are integrated to existing materials that we know of, such as brick, concrete, glass, fabric etc., to improve their physical qualities and performance. A few well known examples include photochromic or thermochromic plastics that change color when exposed to UV light and with temperature differences; dirt proof glass with titanium dioxide coating that does not allow rain drops to adhere to its surface; or fabrics with integrated phase change materials that capture and emit heat when needed etc., (Klassen 2008). This approach shows that with embedded technologies a material's properties can be enhanced to harvest, transfer and release energy only when it is necessary and implies a new kind energy efficiency.

Materials in architecture can be conceptualized as dynamic matter that alter their behavior and are capable of responding to thermal, luminous, acoustical energy fields (Klassen Fall 2006 & 2008). Further, sensors embedded within the building skin that are capable of responding to stimuli from water, heat, air pressure, sound and light can help create dynamic environments that remind people about the energy exchange between materials and the spaces they occupy.

This approach to materiality in return can enhance our perceptions of the changing weather conditions and make us live more in tune with them rather than simply relying on mechanical systems to keep buildings at steady lighting/temperature levels that contribute to climate change. This way the discussion of built environments can be taken outside of the domain of ugly and beautiful and their association with static structure and form. We can visualize buildings as hot, cold, wet, dry, bright, dark, and malleable thus emphasizing their performance and transformation with weather conditions (Figure 4).

## PROTOTYPES

**Figure 5. Poetry appearing with rain.**

By using the discussion of material innovations and their relevance in architecture as a tool, the following design/research investigations are derived from the desire to celebrate and sustain the changing conditions of the atmosphere and make them resonate within the building fabric. These conceptual architectural ideas and prototypes are developed as building canvases that allow weather elements to wash away, appear, disappear, reappear, reveal, scatter, accumulate and transform. The design elements become part of our changing perception of the built environment over time and are neither transportable nor permanent. The first iteration prototypes are intended to remind people of the changes materials undergo with varying atmospheric conditions by revealing the process of freezing, getting wet, reflecting/ absorbing light or moving around in the wind. The second generation prototypes catch, collect or restore the weather elements and lastly reuse them thus contributing to the regeneration and remittance of energy when needed.

## RAIN

A gusty freshening of humid air,
With showers laden, and with fragrance rare;
And now a little sprinkle, with a dash
Of great cool drops that fall with sudden splash;
Then over field and hollow, grass and grain,
The loud, crisp whiteness of the nearing rain.

(Pauline. E. J)

**Figure 6. Poetry appearing with rain.**

Although the energy exchange between materials and the atmospheric substances is not visible to the eye, the differences in air temperature, pressure and density affect the thermal, electrical, chemical, optical and mechanical properties of materials and alter their physical qualities. The following experiments with rain focus on energy exchange between water and the fabric and its visible effects (Figure 5).

Water is absorbed into fabrics due to negative and positive bonds created between water molecules and the molecules that make up the fibres. Plastic, Teflon or Silicon waterproofing coatings of architectural fabrics work on the principal of eliminating this bond with the fibres and thus render the material non-absorbent.

The poetry prototype is conceptualized to combine hydrophobic and hydrophilic fabric surface structures. The base fabric contains many spikes and depressions at microscopic level, similar to a lotus leaf, that allow the rain drops to form a sphere and roll away rather than adhere to the fabric. The overlay fabric that contains the text is conceptualized to have a hydrophilic surface structure that absorb and accumulate the rain drops therefore making the effects of the fabric getting wet and poetry visible (Figure 5 & 6).

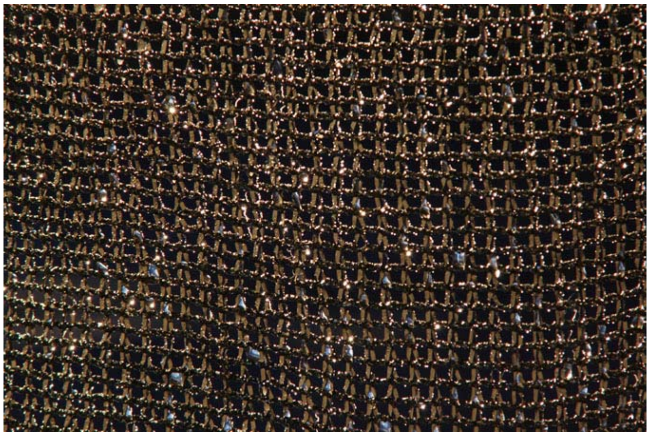

**Figure 7. Rain net.**

Similarly, the rain net fabric is conceptualized as a fine woven mesh with a hydrophobic surface structure to guide and accumulate rain drops for potable water use in the building (Figure 7).

The next phase of investigations integrates the rain collecting mesh with LED lighting and pressure sensors that are activated with rainfall (Figure 8). These exercises not only illuminate the activity of rain collection but also compensate low luminosity levels on cloudy and rainy days. Energy to power the LEDs may come from surface integrated photovoltaic cells, though currently, the ability to generate power from rain’s kinetic energy is being investigated.

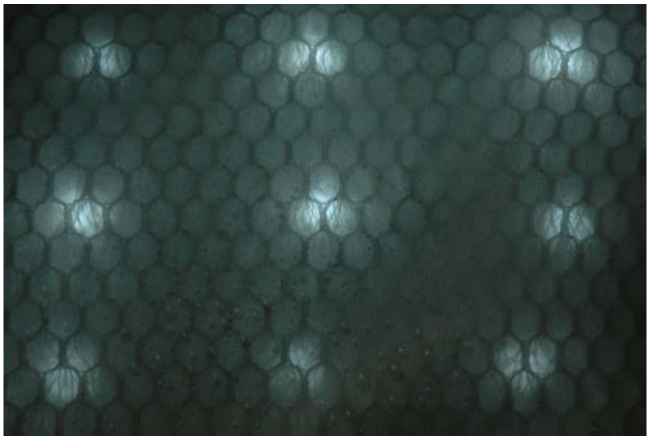

**Figure 8. Rain net with LEDs.**

## WIND

Wind scattered light
from cloud dappled lake
unsettled weather, wind stirred
great lake Ontario storms.

(Zimmerman. K. J)

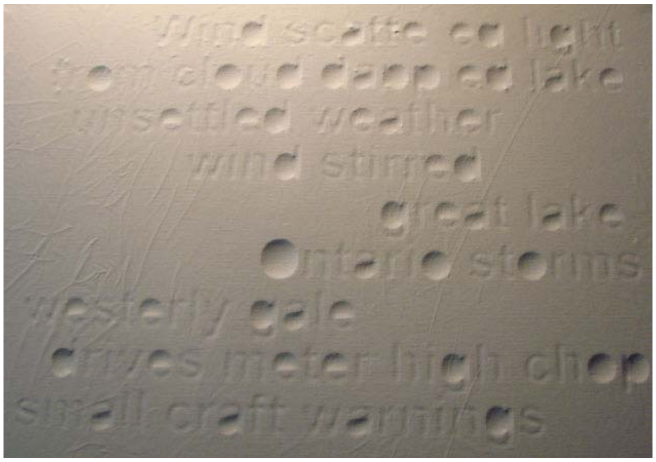

**Figure 9. Wind suction and poetry**

The wind prototypes attempt to make the effects of the wind visible on a building façade by using the oscillating wind movement as a medium of design exploration. Inspiration for the designs is prompted by a study of microscopic reverberations of the fibres, the results of which guide the design intent of revealing the inherent movement within the fabric.

The first set of prototypes in this category reveals the poetry when the random movement patterns of the wind moves the fabric on a building façade (Figure 9). The poetry, cut on to a rigid panel with a CNC cutter, is revealed only when the wind pushes the fabric layer on to this rigid panel (Figure 9).Currently, a lamination technique is being investigated to incorporate semi-rigid and flexible regions in the fabric to reveal the same visual effect (Figure 10).

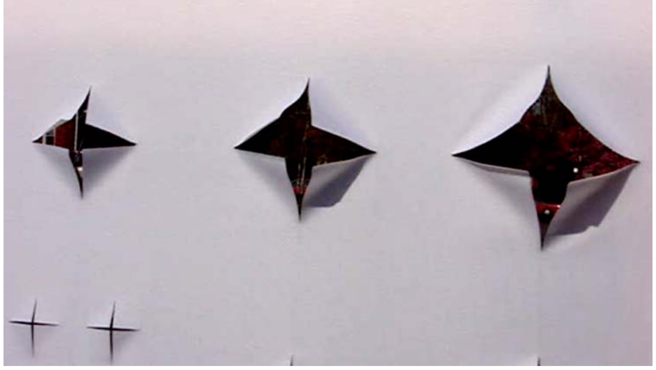

**Figure 10. Wind net**

Wind going through a fabric causes turbulent motion of air molecules. The intensity of this turbulence is determined largely by the fabric's structure and mechanical properties and causes surface ripple effects. By adjusting a fabric's structure at the microscopic level, the reverberation of the fibre and the surface movement of the fabric can be designed to better reveal the fluid air passing through.

The second set of prototypes explores the energy generation capability of wind quill modules when assembled in large numbers. These wind quills, oscillating like leaves in the wind, generate electricity with their motion. In the first prototype (Figure 11), a composite fibre wind quill generates electricity using electromagnetic induction and is attached to an LED. Excess energy is stored in a battery for latent use.

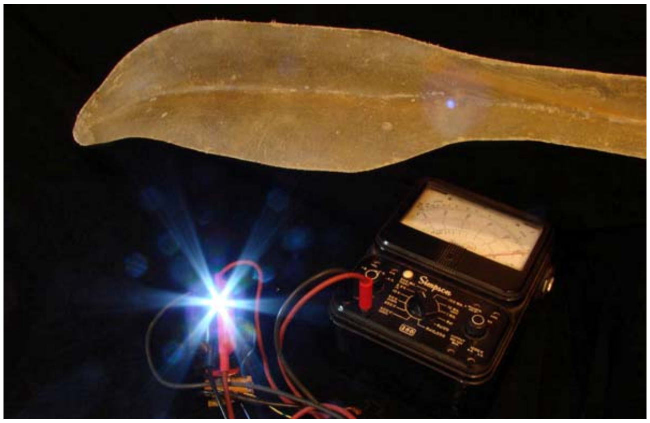

**Figure 11. Wind quill and LED**

The final prototype (Figure 12) explores the generation of localized illumination in response to the random motion of a series of wind quills and makes the wind energy visible when integrated with light. As the wind modulation changes the movement of the fabric, the light pattern/modulation also evolves creating a dynamic fluctuation. This experiment would allow visualizing large scale turbulence that is caused by the wind sweeping around buildings. Currently, this prototype is powered by an external power source and sensors monitor the motion of quills and prompt microcontrollers to actuate the illumination.

An alternative prototype, integration of piezoelectric materials into the quills is being investigated to allow for small scale, robust wind quill arrays. With a piezoelectric composite construction, electricity will be generated from the internal compression and tension forces that result from the wind quills' motion.

**Figure 12. Wind quills with LEDs**

## LIGHT

Midnight storm.  Trees walking off across the fields in furry
naked in the spark of lightning.
I sit on the white porch on the brown hanging cane chair
coffee in my hand midnight storm midsummer night.
The past, friends and family, drift into rain shower….

(Ondaatje. M)

**Figure 13. Light poetry**

Buildings’ high demand for visibility and energy consumption for illumination at night are major concerns that affect the material design investigations. The light prototypes are intended to make building surfaces brighter as well as physically correlate and balance the lighting and temperature level changes of the built elements in relation to atmosphere. For this series of prototypes the base fabric is integrated with one of the following: reflective fabric, fibre-optic filaments, Electroluminescent wire, LEDs with sensors that detect variables of light, temperature and motion throughout the day and night. The design intent enhances responsive built surfaces that are part of the luminous environment that the building is located in and highlight or reflect the changing sky conditions as well use the ambient street and traffic lights in the city. This approach to light responsive building materials is based on the idea of visual blending or the appearance and disappearance of lighting elements with the daily cycle rather than buildings being permanently illuminated.

The light poetry prototype (Figure 13) integrates lettering cut out of reflective fabric as part of the building façade that becomes visible or legible when the light source from street lights and moving cars’ headlights are reflected back to the viewers. The reflective fabric allows light reflection at wide angles from the light source and the added florescence increases low light visibility of building forms and surfaces.

The fiberoptic sky prototype (Figures 14 & 15) focuses on the visual manifestations, on a building material, of various sky conditions and their associated colour values during night and daytime, as well as cloudy, rainy, clear and sunny conditions.

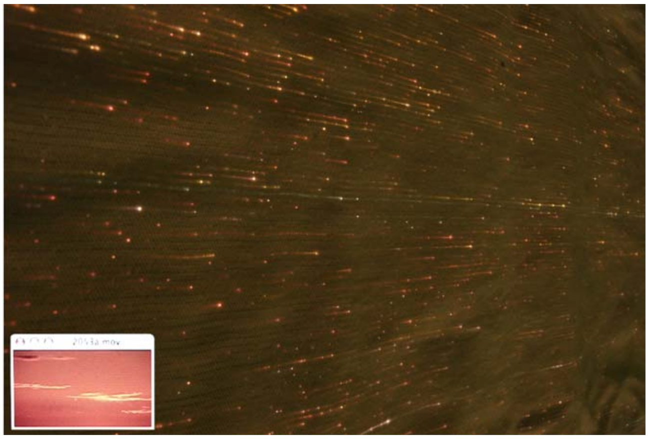

**Figure 14. Fiberoptic sky, sunset**

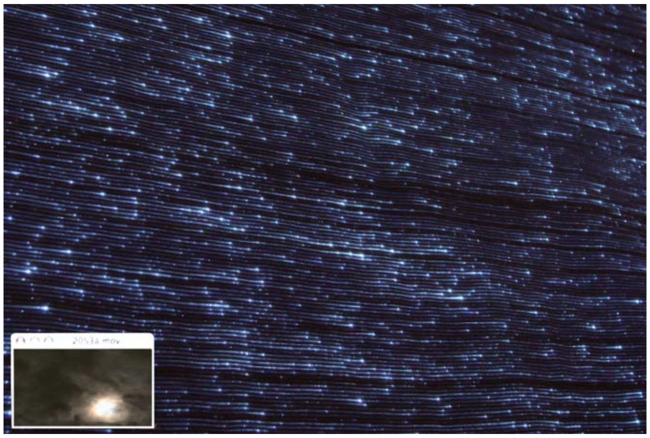

**Figure 15. Fiberoptic sky, night**

In the first prototype, a lens is used to focus the image of the sky on to a bundle of fiberoptic filaments that are individually embedded into the fabric with various curvatures and fractures. The end and side-emitting fiberoptic filaments release the information on to the fabric’s surface therefore changing its light and colour value according to the variations of sky conditions.

The second variation achieves the same effect by using an electrical medium, a Charge Coupled Device, to transmit the sky image when using a fiberoptic conduit is impractical. The captured image is transmitted electrically to the desired location and reconstituted into the fiberoptic embedded material using DLP projection or LED technology.

The light/temperature net prototype (Figure 16) integrates high intensity RGB LED modules and microcontrollers that sense temperature differences. Power generated with solar cells during the day is stored and supplied to actuate LEDs when temperature differences are registered. The microcontrollers register the infrared spectrum of the material from its temperature in a local area and render this information in the visible spectrum of light. The LED modules use a high frequency modulation to vary the intensity of light emitted by the red, green, and blue components and achieve a spectrum that can be perceived by people. The temperature of a building surface can thus vary from red, indicating hot, to blue indicating cold and green, yellow and orange indicating median temperatures. Thus the color of the building skin changes when the building is overheated, cooled or subjected to atmospheric effects such as wind chill. It is intended that our dependency on automatic heating and cooling will lessen with a light net over a building as it will be possible to know when the building is hot or cold.

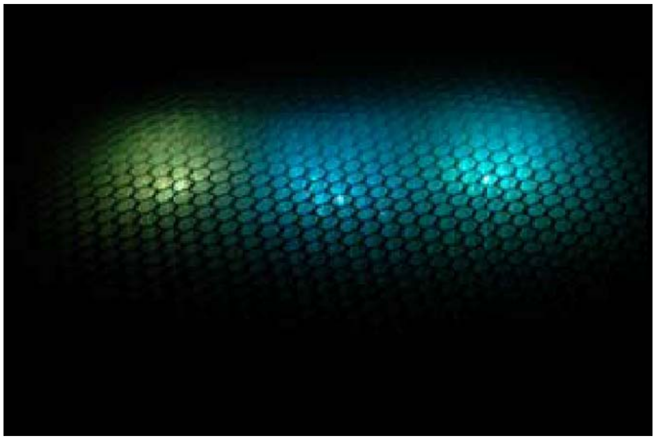

**Figure 16. Light/temperature net with LEDs.**

The air pressure prototype (Figure 18) takes advantage of the flexibility of the Electroluminescent wire and its low level cool glow, generated with small DC power. An ascending or descending graphic wand whose strands become luminous is created when the air pressure is high or low. The EL wire is designed to translate barometric pressure information at the scale of architecture. Its high visibility in smoke and fog and the absence of breakable filaments make the EL wire an alternative to signage and delivering graphic information on buildings.

**Figure 16. EL Air pressure graph**

## CONCLUSION

**‘**There is no city that does not dream from its foundations’. (Michaels, A)

The prototypes unravel the effects of the variations in atmospheric conditions on the building envelope as a ‘creative potential’ for architectural intervention by revealing the inherent energy exchange between atmospheric substances and materials that make up a building. This approach in architecture can help designers conceptualize materials as dynamic matter that alter their behavior and are capable of responding to thermal, luminous, acoustical energy fields. Furthermore, sensors embedded within the building skin that are capable of responding to stimuli such as water, heat, pressure, sound and light can help create dynamic environments rather than static surfaces. This is the context climate change in architecture is dealt within this project to remind the inhabitants of a city about their own contribution to the energy exchange of spaces they occupy and the atmosphere around the building. Future prototypes will focus on heat transfer and C02 (carbon dioxide) emissions as part of the atmospheric substances.

## ACKNOWLEDGMENTS

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