# THE DIGITAL ARCHITECTURE OF TOMORROW

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## Abstract

*This paper presents an ongoing research project about the development of the materials and fabrication techniques for a fundamentally new class of architectural composite. This type of composite, which is a representative example of an even broader class of smart architectural material, has the potential to change the design and function of an architectural structure or living environment. As of today, this kind of composite does not exist. Once completed, this will be the first technology on its own. We believe this study will lay the fundamental groundwork for a new paradigm in surface engineering that may be of considerable significance in architecture, building and construction industry, and materials science.*
*Keywords: Architecture, Smart, Materials, Technology, Future*

## Introduction

Recent developments in digital technologies and smart materials have created new opportunities and are suggesting significant changes in the way we design and build architecture. Traditionally, however, there has always been a gap between the new technologies and their applications into other areas. Even though, most technological innovations hold the promise to transform the building industry and the architecture within, and although, there have been some limited attempts in this area recently; to date architecture has failed to utilize the vast amount of accumulated technological knowledge and innovations to significantly transform the industry. Consequently, the applications of new technologies to architecture remain remote and inadequate. Although, there have been some adaptations in this area recently, the improvements in architecture reflect only incremental progress, not the significant discoveries needed to transform the industry.

However, architectural innovations and movements have often been generated by the advances of building materials, such as the impact of steel in the last and reinforced concrete in this century. This relationship – between new technologies and 'new architecture' is very significant and has always played a significant role in architectural field so that architecture in modern times is characterized by its capacity to take advantage of the scientific developments and technological innovations (Morales 1997).

Based on the digital and technological advancements and the introduction of new design and fabrication tools to architecture, a new way of design thinking has emerged –ways to express an idea as well as ways to create –fabricate and manufacture- usable and meaningful designed environments. These developments are seen as mind-extending or as a catalyst to stimulate designers, to facilitate new problem structuring and construction activities, such as conception, representation, reflection, and production. As a result, a new architectural formal language and grammar, where structure and skin form a new kind of composite materiality, has been emerging. Consequently, an interesting relationship is established between the new geometries and "new materials where new architectural geometries opened up a quest for new materials and vice versa" (Kolarevic 2003).

The composite nature of these new materials is created by the combination of multiple separate layers of different materials into a single material. Certain cognition-driven terms, such as 'smart' and 'intelligent' are started to be used to describe the interactive and built-in programming nature of the composites. There are some scattered attempts of the creation of these materials but currently they are mainly used for limited applications and mostly for aesthetic purposes. A new architectural composite is needed which will merge digital and material technologies, embedded in architectural spaces and play a significant role in the way we use and experience architecture.

This paper introduces an innovative architectural composite material, the digital wallpaper, that will be part of the architectural space and will include circuit elements – transistors, resistors, capacitors, diodes, etc. -- equipped with sensing and computational capabilities in the form of a lightweight, flexible thin film laminate that can be either be applied on top of the wall surface or used as a partition-wall element in itself. This new material is capable of displaying different visual properties on demand. Our approach uses three major pertinent domains in this area: architecture and design; engineering and material science; and construction technology. Together, this confluence will produce an innovative surface material that lies at the intersection of the involved domains. See Fig. 1.

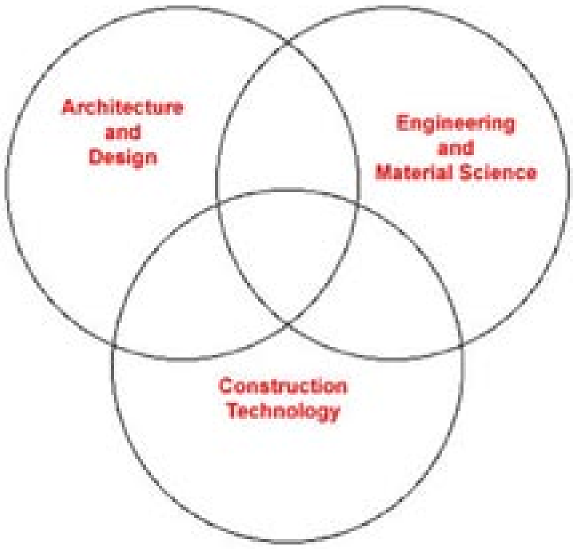


Figure 1: Converging Domains: Architecture and Design; Engineering and Material Science; and Construction Technology

## Approach

This new 'smart material' reversibly switches its properties in response to an external demand. On this 'digital wallpaper', colors, patterns can be set, changed, and adjusted to different tastes, furniture, mood and design trends. Various visual projections –or presentations- would be available, too. For example, picture frames can be created on defined areas on demand and in theory every wall could become a TV screen, including the ceiling! Figures 2 and 3 illustrate concept drawings and actual prototypes (Rogers 2001; Rogers, Bao et al. 2001) of the types of systems that we are utilizing.

Figure 2 Living space enhanced with thin, wall mountable large area displays. Adapted from a presentation by Philips.

The crucial element for these types of systems is the ultralow cost distributed electronics that can control the colors of the pixel elements. We are designing these circuits to have layouts and performance comparable to the circuits that are used in liquid crystal computer displays. Static images as well as full motion video will be possible. For digital wallpaper, it must be possible to build the circuits at a small fraction of the cost of those that use conventional silicon on glass.

In addition, due to considerations of weight and installation, they must be constructed on lightweight, flexible, rugged substrates such as plastic rather than traditional electronic substrates such as glass or silicon. The materials and engineering technologies that can enable circuits of this type do not currently exist. Therefore, one of our primary goals is to develop and demonstrate the necessary materials and fabrication techniques.

We believe that the most promising material for the semiconductor component of these circuits is a printable form of single crystal silicon, which we refer to as microstructured silicon (µs -Si) (Menard, Lee et al. 2004). This new material is just now emerging from our labs. The basic approach in this case is to use specialized

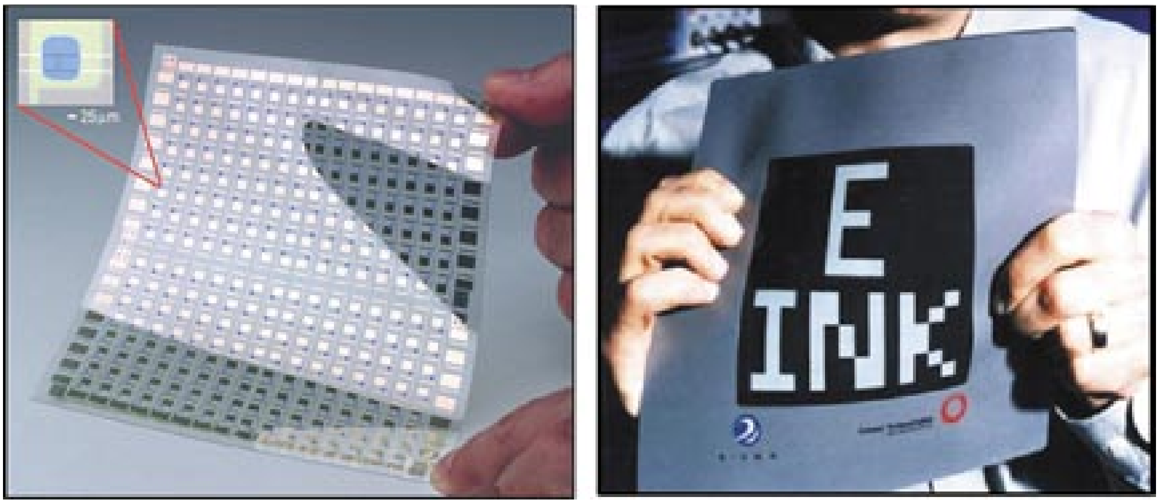


Figure 3 Flexible electronic circuit (left) and paperlike display system constructed with it (right).

etching procedures to slice a standard silicon wafer into microscopic pieces – ribbons, wires, platelets, disks, etc. depending on the application. These pieces can then be dispersed in a liquid solvent from which they can be cast onto nearly any substrate, including low cost plastics. The necessary circuits can then be constructed out of the µs -Si material. The advantages of this approach are: (i) it enables a high quality semiconductor to be integrated onto a wide range of substrates at room temperature and in open air, (ii) it relies on very well developed materials technology – single crystal silicon wafers, (iii) it exploits all of the knowledge of how to build circuits out of silicon, and (iv) it is compatible with printing techniques and other low cost, non-cleanroom based methods for making the circuits.

Figure 4 shows an image of some of this material, in the form of collections of microscopic ribbons (Menard, Lee et al. 2004) . Figure 5 illustrates an array of such ribbons integrated into a device that operates like a high performance, conventional transistor(Menard, Lee et al. 2004). The switching characteristics of devices such as these are almost as good as well engineered transistors on silicon substrates.

They are considerably better than those of conventional

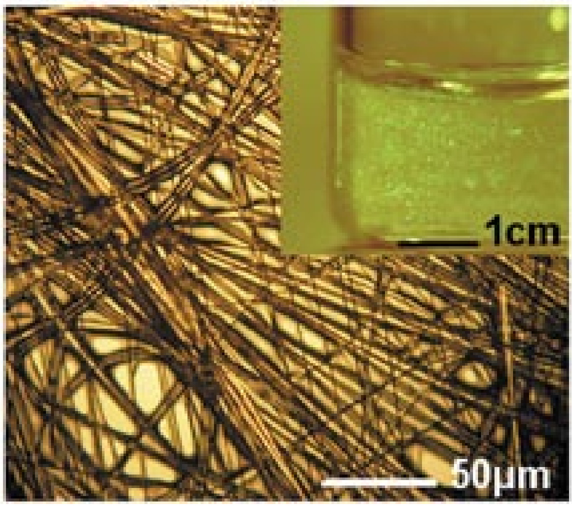


Fig.ure 4. Microstructured silicon, in the form of long narrow ribbons. The inset shows a solution suspension of this material.

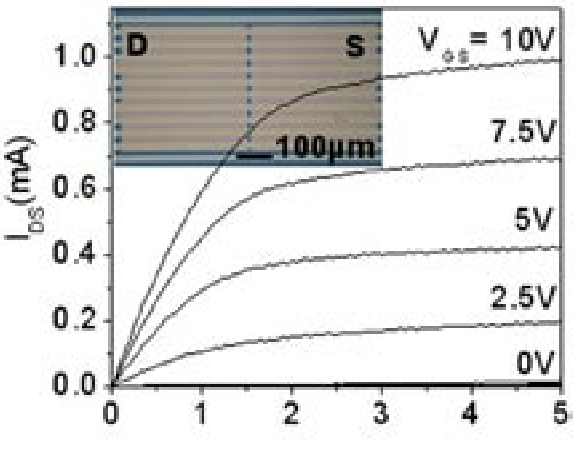


Figure 5. Current-voltage characteristics of a device that uses µs -Si as the semiconductor.

silicon transistors on glass. This new µs -Si technology allows one to consider, in a realistic way, the types of smart architectural surface materials described in this paper.

## Method

The "Digital Wallpaper" prototype is initially applied as an external sheet on top of the existing wall surface. At its technology base, it relies on innovative ways to build circuits out of the µs -Si material described previously. We are developing these concepts and applying them to large area circuits on plastic substrates with designs that specifically address the digital wallpaper application.

We are adapting for use with µs -Si the printing techniques and circuit designs that we developed in the past for organic semiconductor based circuits (Rogers, Bao et al. 2001; Blanchet, Loo et al. 2003). Figure 6 shows an example of a 50x50 cm flexible active matrix circuit that we formed by printing(Blanchet, Loo et al. 2003). New methods must be invented to deposit and pattern the µs -Si to yield similar circuits for digital wallpaper. We are pursuing approaches based on silk screen printing and ink jet printing for this purpose. We are also developing methods for integrating other components of the circuits (e.g. dielectrics and electrodes) directly onto the µs -Si before this material is printed onto the final devices substrates. We believe that these strategies will enable high performance circuits to be formed directly on conventional building materials such as paper and polished stone or wood.

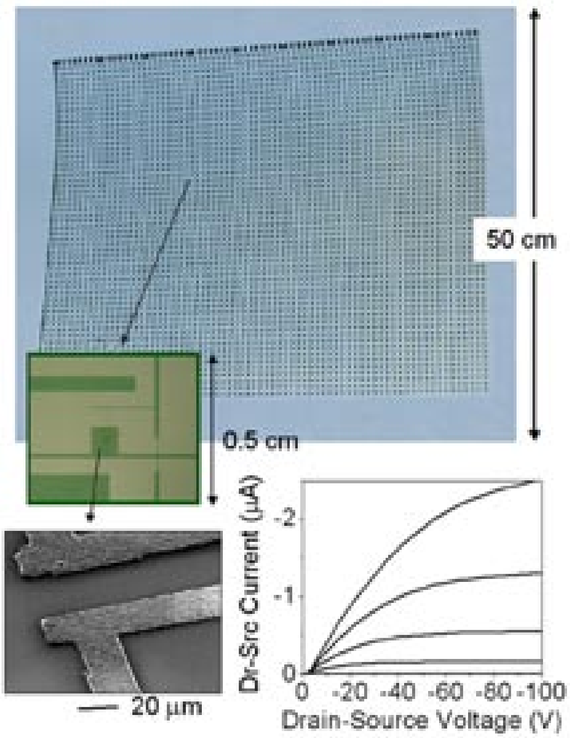


Figure 6.

## Conclusion

This is an ongoing study partially funded by the Research Board at the University of Illinois at Urbana-Champaign. The current challenge is to develop the first phase of the prototype and test it in a non-clean-room based environment. As of today, large scale, flexible display material does not exist. Once completed, this will be the first technology on its own. Next step is the addition of the structural stability to the material and use it as a 'digital' wall which we believe will replace the interior partitions in the near future. In architecture and construction industry, this material can make significant changes in building design, especially in wall-systems and enclosures.

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