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#### **Authors**

Pan, Ning

Postle, Ron

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## “10 Commandments” in Wearable Technologies

By Ning Pan and Ronald Postle

Wearable technologies, also known as smart clothing or e-textiles capable of responding to environmental stimuli, have attracted such escalating interests from both manufacturers and consumers that some experts predict they “...will be as big as the smartphone”. Given the wide coverage by and extreme intimacy between the human body and clothing, the potential for wearable technologies indeed seems to be overwhelming.

For thousands of years, the two basic functions of clothing have remained the same and have served us well, viz. body protection and body adornment, despite tremendous advances in both materials and fabrication. In fact, it is sometimes surprising how little has changed when examining a piece of clothing unearthed from the tombs of ancient history. It is interesting to wonder why this constancy persists when other things in our life, transport, shelter and even food and drink, continue to update their forms and functions.

The textile industry has historically been at the forefront of mechanization and industrialization of traditional manual operations such as spinning, weaving, knitting etc., and of pioneering the chemical innovations leading to the introduction and proliferation during the 20th Century of man-made regenerated and synthetic fibers which have greatly added to the volume and variety of traditional naturally grown fiber raw materials. Textile materials can now be manufactured rapidly on a massive scale at very high speeds with increasingly added functionalities at a very reasonable price.

So now we might be witnessing the initiation of another revolution in clothing through the development of truly wearable technologies where electronics are integrated within the actual textile structure itself rather than as portable accessories such as watches, bracelets, lenses or electronic devices attached to garments. For wearable technologies to gain success in today’s environment, it is of critical importance to explore and understand the causes or reasons behind the seemingly eternity of clothing up to now.

We list here the ten most significant attributes (or the ten ‘commandments’), which are necessary in fulfilling the twin functions of clothing. These ten commandments reveal why our clothing has served us so well for so long:

### 1. Strength and durability

To protect our body from encounter with sharp and hard objects, cloth has to be strong and durable.

### 2. Sufficient stretchability and elasticity

In order for us to function normally, our clothing has to be easily stretchable to accommodate our body movement.

### 3. Lightweight

Nobody wants his/her clothing to be a burden to carry around.

### 4. Body shape conformity

Clothing should cover us elegantly so that we do not appear like ...the “tin man”.

### 5. Breathability and wear comfort

Overall comfort must be maintained so that our skin can “breathe” and the secreted sweat be channeled away and evaporated.

### 6. Thermal consideration

The very first reason for clothing is to keep us warm in cold weather.

### 7. Skin safety and contact comfort

Our clothing under all circumstances should avoid posing any intolerable sensation or hazardous consequence for our body and skin.

### 8. Refurbish-ability

Clothing has to be washable/cleanable, and repeatedly.

### 9. Aesthetic considerations

Clothing is designed, printed, dyed, colorized for ornamental purposes.

### 10. Cost

The price, although not an intrinsic property, is needless to say important in determining the consumer acceptance and commercial success of any clothing.

Let us now look at how our current form of clothing satisfies simultaneously so many – some seemingly mutually exclusive and demanding – requirements:

(a) Most if not all fibers used for clothing are polymeric in nature so that they are light in weight and process-able on a massive scale into yarns, fabrics and eventually into garments. We can thus achieve aforementioned lightweight, flexibility and durability at reasonable cost.

(b) We employ hierarchical structures ascending through fiber, yarn, fabric, apparel, to form porous materials of different capillary pore sizes in order to achieve hydrophilicity, dye-ability, air permeability and comfort.

(c) Friction forces serve as the only adhesive agent in our clothing to assure, apparently contradictorily, both system coherence and inter-component mobility (whether through twisting, entangling, interlacing or braiding). Sufficient integrity is thus maintained in the fibrous network structures where the seemingly opposing properties including strength, pliability, stretch, body-shape conformity are combined harmonically.

These three essential requirements have hence determined, singly or jointly, our current form of clothing. Any attempt to deviate from the three vital requirements would necessarily cause severe deterioration of clothing performance, thus greatly deterring its consumer acceptance. Given current technology and foreseeable future advances, we can therefore predict with reasonable confidence that in any successful wearable technology, polymeric fibers will still form the main frame of the clothing. Any other materials including metals, semi-conductors and electronic devices, can only be incorporated locally in small amount, or in the form of attachable functional patches. Furthermore, an entirely novel clothing system developed by overriding the three basic requirements to replace our current cloth, will unlikely be possible at least in our lifetime.

Many people think that wearable technologies depend solely on the future development of microelectronics and optics and that the textile represents only an inert substrate that plays very little if any creative part. However, in order to achieve commercial success of truly integrated wearable technologies, we must develop the basic elements of new technologies which are compatible with textile manufacturing practices, be it new battery technologies, textile based input and output systems, flexible sensors etc.

For progress in this emerging field, we are highly dependent on meaningful cooperation of creative multidisciplinary research and also on coordinated manufacturing processes between two very different industries, the electronics and the textile/ apparel industries. There is little tradition of communication between these two industries that in addition have very different current levels of commitment towards research and development. Much more active and innovative teamwork between the various sectors of the electronics and textile industries will be essential if wearable technologies in

the near future are going to gain anything like the acceptance of the mobile phone.

There are some non-technical issues as well. Consider for example several thousand people in one location at the same time, a concert hall or a sporting arena, where we are confronted with numerous varieties of textiles and clothing differing in fashion, style, culture, color, and design etc. Compare this vast array with the number of people having the same model of mobile phone or the same vehicle model in the parking lot. Also, changes in fashion are occurring at an ever increasing pace due at least in part to the relatively low cost of clothing. The price will inevitably increase if we add more expensive electronics to the clothing. Will we still be able to recycle as readily a totally disfavored T-shirt in which a sophisticated computer is embedded?

Wearable technologies are therefore most likely to penetrate first into the markets where performance and added functionality are critical such as in the military, sports, medical fields, and under extreme conditions, e.g. firefighting and polar explorers. Various other applications will only become integrated into everyday clothing after the above functionalities and business issues are resolved and proven. **CTI**

#### About the authors

Ning Pan, Ph.D.

Professor in Fiber & Polymer Science

Division of Textiles

Biological & Agricultural Engineering

The University of California at Davis

1 Shields Ave., Davis, CA 95616

Email: npan@ucdavis.edu

Fax: 530-752-7584

Tel.: 530-752-6232

Ronald Postle, Ph.D.

Emeritus Professor of Textile Physics

Professorial Fellow

School of Chemistry

Room 161, Chemical Sciences Building

University of New South Wales, UNSW

Sydney, NSW, 2052, Australia

Tel: +61 2 9385 4677

Fax: +61 2 9313 8585

r.postle@unsw.edu.au