Incorporation of SMA Technologies in Fashion Underwear Apparel

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ABSTRACT
The experiment has as main goal identify consumer needs for underwear bra apparel that deserves singular research attention, in order to associate it with a smart technology, the Shape Memory Alloys (SMA) as well as with fashion design. The SMA will be incorporated to provide functional behaviour to the bra, besides physiological and psychological comfort in a manner to supply woman needs related to the bra performance. The SMA was blended with cotton to improve the processability of bra knitting structure construction. Through a heat treatment the SMA bra was shaped set on the desired shape design. After high heat treatment it can be incorporated in the bra between two layers of fabric to improve the bra touch. When contacted the woman breast, the SMA bra will recover its original shape, providing a better performance covering problems like wrinkle and deterioration behaviour, generated by the way the bra is stored, or submitted to washing or drying machine.

Author Keywords
Fashion Design, Smart Textiles, Underwear, SMA.

INTRODUCTION
Throughout history, design, fashion and textiles have been closely related to scientific and industrial innovation. We can see radical technologies that are poised to redefine how we think about the design, manufacture, and consumption of fashion. [1] Material innovation is an important focus on creativity in the field of textiles today. [2] and important experiments are taking place into the development of new materials and many fashion designers consider technological fabrics the future of fashion. Designers are frequently alert to the latest treatments as they can transform a traditional textile, updating it for a contemporary look. [3] The new fibres are a product of scientific research which has during recent decades brought a revolution to the textiles industries of the world comparable with the industrial revolution. [4] Not only look but also the feel and performance are influencing fashion designers. Technology applied to fashion help us to adapt to comfort, freedom, versatility and functionality. The market for technology products is growing, consumers requirements of products are changing. [5] The customers now expect more from their wardrobes as they expect that the range of new technologies can be even more available to improve the way we live. The underwear is one area of great development that applies new technologies to improve a range of comfort factors. Then, this is the main goal of this experiment, combine the consumer needs both functional and aesthetics for the underwear developing a bra with the SMA, and take advantages of the features of this technology adapting it to the intimate apparel.

BRA CONSUMER REQUIREMENTS
In contrast to outer apparel, the intimate apparel deserves singular research attention. The underwear indicates a consumer involved by a complex range of interlinked factors like: functional, physiological, psychosocial and economic [6]. In terms of physiology, women's breasts are not symmetrical, and no two female shapes are the same. To compound the physiological problems, lifecycle stages affect breast shape. [7] The bra as a harness performs the important function of breast support to a vast range of physiological shapes, sizes and tissue density/elasticity [8]. The bra affects the perceived comfort, contour, posture, breast health and physical performance of the wearer [6]. Therefore fit is critical.
At a psychosocial level, bras, by their design alter the shape of breasts for fashion [9], as well as breast presents a visible contoured cue to the world, it is intrinsically linked with a woman's sexuality, body-image and social image.
As mentioned by Hart and Dewsnap [6], the problems recognized by the consumers about the intimate apparel, especially about the bra, which make them purchase a new one are: the apparel's loss of functional support through deterioration of elasticity; the decline in bra's aesthetic appearance and a change in the wearer's physiology driving the need for a different bra size. Besides the functional aspects, the consumer is leaded to buy because of the aesthetic value, in order to make consumer feel special and pretty.
The underwear appearance aspect, which sometimes is damaged because of care on washing drying machine, or the way the underwear is stored during a travel or on the
wardrobe, generates negative effects on the bra like: the wrinkle and the deterioration behaviour, which prejudice the fit and the aesthetic aspect. In order to avoid the wrinkle aspect, the material that will be used on the design development of the bra, the shape memory alloy, will be applied on the pad that is the area with more deterioration of surface, because is the area which has more contact with the breasts. The main feature of the SMA that will benefit the bra pad is the shape memory effect. This behaviour will provide to the bra pad remember the original and flat shape, when it gets contact with the human body.

SMART MATERIALS

The expertise gained from many years of technical textiles is being more intimately married with expertise from other engineering, scientific and design sectors, giving rise to a new breed of smart technologies. [10] Some materials were used originally for space and military applications, but now, designers are using them in unusual ways for clothes. [3] Smart materials respond to external stimulus: to heat, to light, to pressure, and to chemical changes; And they can act by changing shape, harvesting solar energy, conducting electricity or light. [2] Types of smart materials include shape memory alloys and polymers (SMA and SMP), magnetorheological materials (MR), electrorheostatic materials (ER), piezoelectric materials (PZT) and electroactive polymers. [1] Shape Memory Materials are able to sense a change in temperature and react by changing into a prescribed form. As an adaptive material they can convert thermal energy into mechanical work. [11] If deformed mechanically below the transformation temperature, they will be able to regain their original shape back, once the temperature increases above the transformation temperature. This transformation occurs because the material changes its internal structure with temperature. In the case of shape memory alloys (SMAs), for example, at a low temperature, the structure of the materials changes to a martensite phase, where they can be easily deformed. Upon heating, the structure changes to an austenite phase, and the programmed shape is recovered as the material “remembers” its original shape triggering the Shape Memory Effect (Figure 1).

![Fig. 1 Schematic diagram of shape memory effect in alloys.](image)

Table 1. Transformation temperature range and strains.

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<thead>
<tr>
<th>Transformation temperature range</th>
<th>+25 to +35°C</th>
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<tr>
<td>Transformation strains up to 1 cycle</td>
<td>up to 8 %</td>
</tr>
<tr>
<td>up to 100 cycles</td>
<td>up to 5 %</td>
</tr>
<tr>
<td>up to 100,000 cycles</td>
<td>up to 3 %</td>
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</tbody>
</table>

The physical properties are illustrated on the table 2. The corrosion property which is excellent is very important because it’s resistant to deterioration, essential feature to materials that are submitted to washing machine process. Also biocompatibility, which is excellent, is a key factor resistance, properties that conventional materials do not exhibit [13].

To create the SMA, the alloy is formed and held mechanically in the required shape. Through a process of high heating and rapid quenching, the relationship between the different crystal structures is set. The SMA retains its programmed shape at ambient temperature but when deformed it will always return to its original shape when the appropriate stimulus is applied. [12] The most common type of SMA is the Nitinol, that presents advantages in comparison to other types of SMA.

The SMA has been used on underwire women’s brassieres [14], because of its pseudoelasticity property. NiTi SMA underwires offer improved comfort. An additional advantage is the fact that the pseudoelasticity NiTi wires are resistance to permanent deformation which can be the result of washing and drying cycles.

METHODS, RESULTS AND DISCUSSIONS

The SMA applied on the experiment was purchased from Memory Metalle and has specific properties and settings, appropriated to the behaviour required to the bra design development.

The alloy reference B, is the standard actuator nitinol alloy for body temperature shape memory applications. The transformation temperature that triggers the Shape Memory Effect of the alloys and its transformation strains are illustrated on the table 1. This alloy is used in applications, where a shape change due to changes in temperatures around body temperature is required, them, is more appropriated for the application desired.

The surface condition chosen is the oxide surface, without treatment, in a diameter of 0.127 mm.
because the material will be used with a high proximity with the human body.

**Physical properties:**

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<tr>
<td>Shape setting temperature</td>
<td>400 to 550ºC</td>
</tr>
<tr>
<td>Corrosion properties</td>
<td>Excellent</td>
</tr>
<tr>
<td>Biocompatibility</td>
<td>Excellent</td>
</tr>
<tr>
<td>Density</td>
<td>6,45 kg/dm³</td>
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</table>

**Table 2. SMA Physical properties**

The application of SMA is made by developing a bra pad with SMA wire by knitting process. Unlike the other experiments related to SMA in fabrics, which first train the yarn and then incorporate it to traditional yarns (Stylios), this experiment blends the SMA wire with cotton yarn before training the SMA. This blend provides a better processability on knitting process, because the SMA has bad adherence, which prejudice the development of the structure. The knitted structure can be observed on figure 2.

After the SMA was shaped set on ceramic base which provides the pad shape, it has to be heat treated. The structure has to be submitted to 550ºC in a furnace about 5 minutes. The cotton blended with the SMA will disappear due to the high temperatures that the material is submitted. Them, after remove the structure from the furnace, the knitted structure is 100% SMA. The heat treated structure can be observed on figure 3.

After heat treatment of SMA structure at high temperatures, it can now be incorporated as a pad on the bra, placed internally, sandwiched between two layers of fabric, in a manner to provide a better comfort to the user.

Now, if the bra is bent, it can recover its original shape upon heat treatment. When the bent SMA bra contacts the woman breast its functionality triggers due to the contact with the body temperature, returning to the shape which was set by heat treatment.

The figure 4 and 5 illustrates the structure without the internal layer of fabric in order to show the bra performance upon bent (fig. 4) and then, submitted to a heat treatment at 37ºC about 60 seconds, simulating the woman body superficial temperature, the structure recovers its original shape. (fig. 5).
Fig. 5 – SMA structure recovers its original shape upon heating.

The SMA bra structure besides having shape memory properties gives to the bra the original shape design upon contacting the woman body, it alters the breast size because of the thickness of the knitting structure, and consequently it makes the woman feel better at a psychological level. The open knitting structure allows the passage of air, becoming the structure breathable, providing physiologic comfort.

CONCLUSION

The underwear apparel has a wide range of opportunities and challenges. The challenges related to the development of a SMA bra pad have even more challenges due to the difficult processability of the material. The blend of SMA wire and cotton yarn has provided a better processability, because cotton improves the SMA adherence. The experiment shows that the incorporation of cotton in SMA structure does not damage the shape memory effect of the pad. Anyway, improvements must be done mainly related to the handle of the pad and on the design structure of the bra.

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REFERENCES