# Future Development in the Beauty Industry: A Review of Beauty Technology Case Studies

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**Abstract:** *The present study aims to find whether the beauty industry, which has developed around traditional cosmetics, can advance to beauty technology inspired by creative and artistic ideas for interactive cosmetics. First, interactive materials are defined as materials produced using embedding technology into beauty products based on conductive inks, conductive nail polish, conductive artificial hair, and other new materials. This enables a wide range of applications in beauty technology. Second, understanding the skin, its appendages, and the movement of the body through muscle and skin interaction case studies is essential in the body interaction of beauty techniques. On-skin interaction can be used as an input for wearable devices, and different body parts can be used for mobile interactions. Third, Beauty Wearable Devices are defined as cosmetic computing, a concept that expands the vocabulary of on-skin wearable devices. It is a beauty technology such as a dynamic display with no internal power supply. Fourth, makeup based on projection mapping is a method of non-rigid expressive augmentation. This can create live makeup. As a result of analyzing classified case studies, we conclude that the common point of the development direction of beauty technology is changing from traditional beauty products to interactive beauty products.*

**Keywords:** *beauty technology, beauty industry, interactive material, on-body interaction, cosmetic computing, living makeup*

## 1. INTRODUCTION

The term "beauty technology", coined by Kaita Vega, refers to a wearable computing subfield that uses body surfaces as an interactive platform by integrating technology into beauty products applied directly to the skin and its appendages (e.g., hair and nails).

Beauty products are commonly used in daily life to alter and enhance people's visual appearance. Moreover, due to their proximity to the skin, daily use, and acceptance, such products provide novel interaction possibilities. Specifically, it is possible to embed electronics and to create unnoticeable wearable devices that not only camouflage the electronics within cosmetics but also conceal interactions by using normal human behaviors [1]. This expands the concept of traditional beauty products.

The present study explores the future potential of the beauty industry through case studies of beauty and art technology. To this end, we review available case studies in the following five areas: (1) conductive materials, (2) muscle-based interaction, (3) on-skin interaction, (4) beauty wearable devices, and (5) projection mapping. Based on the results of the analysis, the future development potential of the beauty industry was considered by referring to the following four trends: interactive material, on-body interaction, cosmetic computing, and living makeup in beauty technology.

## 2. BEAUTY TECHNOLOGY CASE STUDIES

### 2.1. Conductive Materials

Conductive inks, RFID tags, small magnets, conductive nail polish, conductive artificial hair, and other new materials have enabled a wide range of applications in beauty technology.

Figure 1 shows <LED Henna Tattoos>. In a flashy update to the traditional art of temporary tattooing, Indian designer Amrita Kulkarni has fused conductive ink with her henna practice to create an LED array that is directly applied to the skin using a line of skin-friendly paint. Conductive materials for the project were mounted LED lights powered by small 3V batteries atop the intricate patterns. The most important aspect of conductive art was figuring out how thick the design should be, as line thickness is inversely proportional to the ink's generated resistance [2].

**Fig1:** LED Henna Tattoos

Beauty Tech Nails are artificial fingernails embedded with RFID tags, small magnets, and conductive nail polish. The RFID glass capsules embedded in the nails are used with an RFID reader that can identify each tag and trigger an application based on the input of one nail or the combination of a sequence of nails in a specific pattern. The magnets can amplify the wearers' sensing abilities by allowing them to sense magnetic fields and objects with magnetic switches, such as smartphones and tablets. The conductive nail polish can be used to complete a circuit when it comes in contact with other conductive materials [3]. The chosen RFIDs' dimensions are 12.25mm in width by 1.93mm in diameter. They are hidden either into a plastic/acrylic gel sandwich nails or salon gel nails. Gel nails are a type of artificial nails that most closely resemble natural nails. The gel is applied to the nails in several thin layers, with each layer being cured under a UV lamp for about 2 min. After drying, the tag is placed on the top of the basecoat. After that, several thin gel layers are applied until they completely cover the RFID. A decorative design using nail polish is then applied to hide the RFID at the end of the process [4]. Figure 2 shows this process.

**Fig2:** Prototyping beauty tech nails. Gel nail process. Step 1. RFID tag placed on the top of the dried basecoat gel, Step 2. curing gel layers, Step 3. decorative nail design.

Hairware, invented by Katia Vega, uses a chemical plating technique that makes the artificial hair extensions to be conductive; however, at the same time, it remains to look like regular human hair. The chemically metalized hair extension is a prototype of beauty technology that connects to a microcontroller, turning it into an input device to trigger different objects. The chemical process is performed in two phases: activation and electrolysis. During the first phase, artificial hair extensions, being plastic non-conducting surfaces, require some kind of activation to enable them to be submitted to an electrochemical process. The first activation uses hydrogen and tin chloride. Then, a silver nitrate solution is added for the second activation, where the extensions are set up to catalyze electron transfer reactions, making them ready for metalizing. Next, they are platted using electrolysis. Copper is electrochemically deposited to make them electrically conductive, while black nickel gives the natural black effect. The electrolysis process requires a copper plaque [5]. Figure 3 shows the hair extension during the metalizing process.

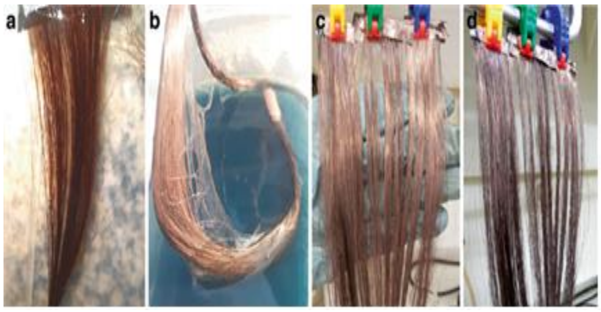


**Fig3:** Hair extensions visualizations after the chemical process: (a) after Activation 2, (b) copper electrolysis, (c) copper acid, (d) black nickel electrolysis.

### 2.2. Muscle-Based Interaction

In recent years, beauty technologies that detect information in the body, such as blinking, pulse rate, respiration, or facial expressions in the muscles under the skin of the face, have been increasingly developed. These technologies have become a key component of on-body interaction in beauty technology. Beauty technologies such as Conductive Makeup and FX e-makeup interpret facial expression micro-movements like blinking and facial movements

Blinklifier (see Figure 4) is an application of conductive makeup that senses muscles by applying conductive materials. To avoid using any electronic component on the wearer's face, skin conductive material is applied as a black eyeliner to connect conductive fake eyelashes to a headband. This eyeliner is a conductive tape that starts with the shape of an upper or lower eyelid and terminates as a slight line. Black paint covers the silver color, giving it a black eyeliner look. These eyeliners are placed in parallel using human skin glue that sticks the eyeliner in the position and, at the same time, isolates the conductivity from the skin [6]. By embedding technology into this headdress, a new collaboration between art and technology has led to the creation of Blinklifier. It follows the natural eye muscle contraction and extends the motion into a visible light array. It also responds to the specific eye movement patterns of the wearer and amplifies emotions that the wearer wants to communicate by presenting noticeable exaggerated visual compositions. Different light patterns show up when the wearer winks with her left, right, or when she opens and closes her eyes [7].


**Fig4:** Blinklifier. (a) 72 LEDs with creating blinking

patterns on the headdress, (b) Metallize fake eyelashes to capture the blinking motion and use a conductive material as eyeliner to connect the eyelashes with the wearable device.

FX e-makeup (see Figure 5) is a Beauty Technology that uses special effects makeup to hide electronic components that sense facial muscle movements, acting as a second skin. When strategically placed on the muscles, FX e-makeup sensors act as switches. Sensors are connected using the FX makeup. Special effect makeup materials are combined with beauty technology sensors for a precise application to specific muscles. Finally, face paint is used to color the user's face black [8]. Figure 5(a) shows the eyelid sensor that senses blinking when the lid is tightener and the contacts touch each other. Figure 5(b) shows the sensor located on the brow, associated with the outer low brow raiser action unit activated when the user raises her eyebrow and the contacts touch each other. The sensor in Figure 5(c) is associated with the lip pressor action unit that activates when both lips are pressed together. Finally, Figure 5(d) shows the sensor associated with the jaw drop, lips part, and lip corner puller action units. It senses a smile when there is no contact, in the opposite way to the other sensors [9].

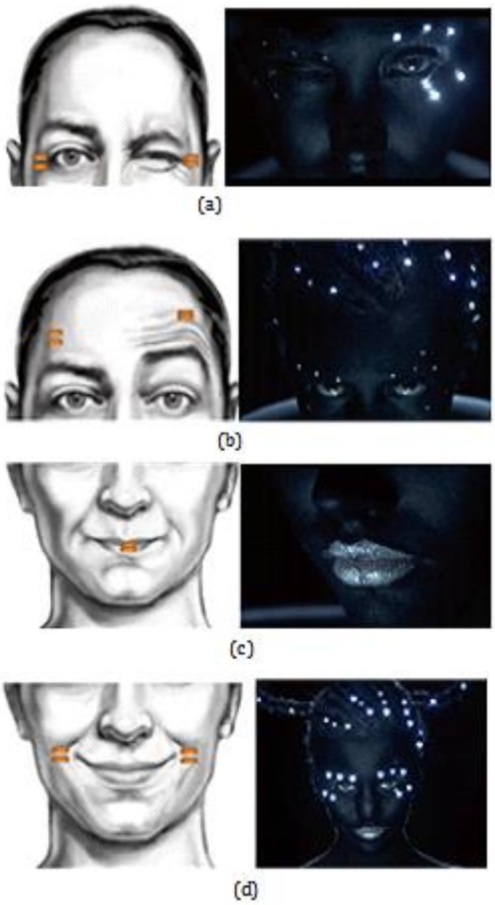


**Fig5**: (a) Eyelid sensor. Image reproduced with the permission from Gabriella Chávez (b) Eyebrow sensor. Image reproduced with the permission from Gabriella Chávez (c) Closing lips sensor. Image reproduced with the permission from Gabriella Chávez (d) Smile sensor. Image reproduced with the permission from Gabriella Chávez

### 2.3. On-Skin Interaction

On-skin interaction is an emerging stream of human-computer interaction that uses the skin as an interactive surface for mobile computing. Skin provides a large input surface, which is frequently easy to reach and fast to interact. Therefore skin has great potential as an input surface for mobile devices [10].

Skintillates (see Figure 6) is an epidermal wearable interactive device that mimics tattoos—the oldest and most commonly used on-skin displays in the human culture. Skintillate devices can serve as passive and active on-skin displays, capacitive and resistive sensors for electronic device control, and strain gauges for posture detection. Similarly to traditional tattoos, skintillates can be customized to be a variety of different shapes and colors to fit the user's intended functions and aesthetic desires. In Figure 6, we show several examples of public and private decorative skintillate displays. Figure 6(a) shows a skintillate dragon tattoo with red LED eyes electrically connected to a watch that could potentially serve as a point-light display for a smartwatch. Figure 6(b) demonstrates a back tattoo with LEDs that flash with the beat of the music controlled by an Arduino hidden under the wearer's clothing. The power pads, which are traditionally circular or square in printed circuit boards, are designed to resemble wings to fit with the aesthetic of the art layer of the tattoo. In Figure 6(c), we demonstrate the potential of using skintillates as a private wearable display for intimate bio-data. In Figure 6(d), we show the possibility of incorporating a skintillate display with an existing permanent tattoo. We omitted the art layer in this device and traced one of the tree branches on the silver ink conductive layer to power three LEDs to light up the tattoo flowers [11].


**Fig6:** Example of skintillates tattoo displays. (a) a dragon skintillates display is powered by the watch and could serve as a point-light display, (b) a back skintillates tattoo that flashes with the beat of the

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music around the wearer, (c) a private skintillates tattoo flashing according to ECG signals, (d) a skintillates tattoo without a printed art layer decorates an existing permanent tattoo.

ChromoSkin (see Figure 7) is an interactive eyeshadow that consists of thermochromic pigments activated by electronic or ambient temperature conditions. ChromoSkin explores the concept of dynamic makeup as an expressive skin display that changes colors according to one's mood, bio-signals, or even information input designated by the wearer. The current prototype can change color according to light activation (e.g., day vs. night). For example, the wearer might prefer a darker eye shadow when she is working during the day, but change to brighter colors for evening social functions [12]. This means that thermoreceptors throughout the skin sense warm and cold temperatures. These receptors not only detect ambient temperature changes, but can also detect localized temperature differences [13]. ChromoSkin is an initial prototype of a color-changing eyeshadow system, showing the potential to extend the purpose of makeup products beyond decoration. Figure 7 presents the ChromoSkin system design consisting of four layers.


**Fig7:** (a) ChromoSkin worn as eye shadow, (b) ChromoSkin consists of 4 layers. Each layer is shown individually, stacked on top of each other.

### 2.4. Beauty Wearable Devices

Beauty wearable devices in the form of cosmetics are articles of personal fashion and must fit the wearer's sense of style. In addition, a clear understanding of the wearability of beauty wearable devices could lead us to envision the interplay between the body and proximate devices.

Lulin Ding, an industrial designer, translated the idea of eyeshadow into a digital form using LED lights, creating a piece that merges beauty, technology, and art. This Digital Eyeshadow (see Figure 8) responds to the eyelid movement. When the user blinks or closes their eyes, the light will emit from the device painting across the eyelid. To digitize the object, even more, we programmed the individual LEDs to vary their brightness. This added feature allows different patterns to light upon the eyelids. The wires are insulated and held in a wireframe that balances on the face and is tucked behind the ear. The lilypad is lightly weighted to keep everything in place [14].

**Fig8:** Digital Eyeshadow

LED Eyelash (see Figure 9) is a project that speaks to many Asian women's desire to have bigger eyes. It features a sensor to turn on and/or off. The sensor can perceive the movements of the pupil in the eyes and eyelids. If you wear it and move your head, LED Eyelash will flicker following your movements. It is as simple to use as wearing false eyelashes and can be easily removed [15]. LED Eyelashes attach SMD LEDs to thin wires for digital makeup effects.

**Fig9:** LED eyelashes by Soomi Park (2007)

As a demonstration of the potential for cosmetic computing and hair as a unique platform for interaction, HäirIÖ (see Figure 10) augments hair with both touch input and visual output. HäirIÖ uses thermochromic pigments and SMA (Shape Memory Alloy)to output visible change in color and shape, reflecting and enhancing the natural and cultural malleability of hair. Furthermore, using shape-changing capabilities, HäirIÖ can transmit subtle haptic communications by stroking or tapping. HäirIÖ uses Swept Frequency Capacitive Sensing to detect and interpret how users interact with the extension. Microcontrollers, sensors, Bluetooth modules, and other components are embedded in accessories or hidden in the hair itself. As such, HäirIÖ combines input with output, incorporates smartphones and other devices into the interaction cycle, and creates novel and rich interactions [16].

**Fig10:** (a) HäirIÖ prototype before miniaturization, (b) exemplar HäirIÖ hair accessory form factors, (c) HäirIÖ uses Swept Frequency Capacitive Sensing to detect natural hair interactions, (d) HäirIÖ color-changing properties using thermochromic pigments, and (e) shape-changing properties using Nitinol wire

AlterNails (see Figure 11) are small interactive electronics that attach to fingernails with commonly available acrylic nail glue. AlterNails are personal wearable devices that embed interaction, information, and fashion while avoiding the need to replace or charge batteries. The heart of this device is a custom-built printed circuit board (PCB). The PCB contains an ATTiny85 microcontroller, an analog accelerometer, a wireless power receiver with an attached coil, and an e-ink segmented display. When a user interacts with an AlterNail enabled smart object, power is transferred from the object to the AlterNail. Each of these AlterNail-enabled smart objects is programmed with a unique vibration pattern. Upon start-up, the AlterNail uses the accelerometer to detect these vibration patterns and to determine which object the user is interacting with. Once the object is recognized, the e-ink display updates. AlterNails are powered wirelessly through objects and provide a framework for new interactions that go beyond current mobile devices [17].

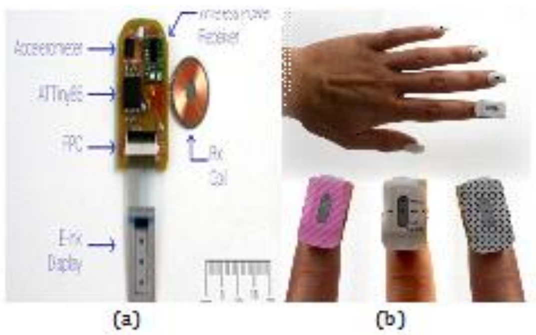


**Fig11:** (a) AlterNail with an accelerometer, ATTiny85, a wireless power receiver, inductive coil, an e-ink display,(b) AlterNail being worn, and the closeup of an AlterNail design.

## 2.5. Projection Mapping

Projection mapping combines the traditional projection technology with software that conforms to the projected media to fit within the boundaries of a three-dimensional surface, rather than a flat, rectangular screen. This allows artists to design motion sequences that follow a unique pathway of planes, curves, and crevices, embracing the architecture and structure of the projection surface as part of the visual story [18].

Makeup Lamps (see Figure 12) is the first system for live dynamic augmentation of human faces, using projector-based illumination to alter the appearance of human performers during performances. Makeup Lamps are the first real-time, non-rigid dynamic projection method to augment human faces with adaptively projected content depending on facial semantics. The Makeup Lamps system is primarily designed for high performance, minimizing the overall latency through a combined multi-threaded CPU and GPU implementation. The developed algorithms, combined with the presented hardware, can produce convincing illusions, which are perceived as being fixed onto the mimics of the augmented human face. This effect is due to a successful compensation of the unavoidable overall system latency through adaptive Kalman based filtering and prediction. This method is not only able to track and match the captured facial shape but also detects its semantics and efficiently adapts the rendered augmentation content accordingly. In contrast to existing methods, the system shown in Figure 12 is the first method that fully supports dynamic facial projection mapping without the requirement of any physical tracking markers and incorporates facial expressions [19]. These technologies produce astounding and realistic facial augmentations, particularly in applications such as film making and avatar-based video conferencing. Leveraging these approaches to physical faces through projection has great potential for a variety of applications.

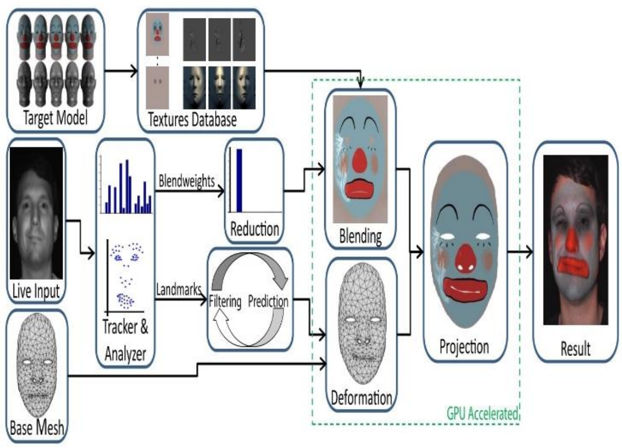


**Fig12:** How to combine different steps to achieve a live facial augmentation system

Using the video mapping technique, Portuguese visual artists Oskar and Gaspar map a tattoo on a person and bring it to life with a customized animation. This project is called "Ink Mapping (see Figure 13). The artists use a projector on human canvases to transform body art into dynamic spectacles [20]. Each animation begins with photographs of the tattoos rendered as 3D models and incorporated into a motion sequence. Then, the human subject is positioned in front of a projector, while video-mapping software is used to line up the animated media with the original tattoo and to get everything to fit within the projection area. A combination of animation and a technique called projection mapping creates magical tapestries of light and movement that flow, slither, and march over a person's body in real time.

**Fig13:** Video-mapping tatto, Oskar and Gaspar

Omote (see Figure 14) is a method of changing the face of a model by applying light as makeup through real-time face tracking and projection mapping. Japanese producer Nobumichi Asai invented a system to project images onto a user's face in real time that can simulate makeup using advanced face tracking and projection mapping. Face tracking is widely used in security and marketing applications; however, Asai wanted to use this technology differently—namely, to express the beauty and the art of makeup, specifically Japanese beauty. Updating the image with every slight movement of the user's face requires a much more precise algorithm than other face-tracking systems. Coordinating the timing of the computer graphic renderings to match the face is impressive [21].

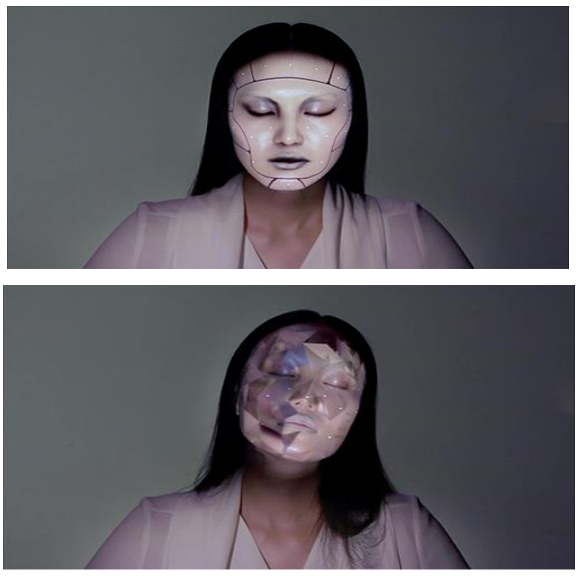

**Fig14:** Omote mask that seamlessly changes from one projected image to another

## 3. DEVELOPMENT POSSIBILITIES OF BEAUTY TECHNOLOGY

### 3.1. Interactive Material

In recent years, despite the emergence of various materials and processes to make products such as makeup, hair, and nails, they still remain static and non-interactive. However, based on RFID tags, conductive inks, thermochromic pigments, small magnets, conductive nail polish, conductive artificial hair, and other new materials, beauty technologies allow the wearer to interact with other electronic wearable devices or objects in their environment. For example, RFID tags fall into the following two categories: (1) active tags that are read/write devices that require a power supply and (2) passive tags that are generally read-only devices. Passive tags draw their power from the reader through inductive coupling that requires proximity. The main advantages of using RFID systems include the non-contact and non-line-of-sight characteristics of the technology. A specific advantage of passive tags is that they are very small and do not require batteries or maintenance, having thus an indefinite operational life [22]. Conductive ink & adhesive have been widely used to explore creating thin, flexible electronic circuitry on the skin in design and research. These materials normally contain powdered or flaked conductive components, such as carbon, silver, and silver chloride. Typical characteristics of conductive glues and inks to consider in soft circuits are resistance, applicable substrates, and application methods. Conductive materials are applied directly to the skin surface or on an interlayer [23]. Therefore, since cosmetics are already an additional layer of the skin, they can be integrated with conductive materials and perform as part of the electronics.

### 3.2. On-Body Interaction

In the context of the wearable revolution, the human body is becoming a new design standpoint. Therefore, in beauty technology, it is necessary to understand the properties, structure, and human body functions of the skin and its appendages for on-body interaction. Such understanding plays a crucial role in the on-body interaction of beauty technology that physically blends into the body. As in the study on ChromoSkin inspired by biological systems with a biomimetic-based approach, direct contact with the skin can significantly improve biological sensing data. Unconventional on-body interaction locations such as nails, hair, eyelashes, lips, and so forth can be used. Another important psychological factor is that skin interfaces usually make strong attempts to endow new abilities to the human body or overcome the limitations of the human body. Differently from wearables, which constantly improve external systems, skin interfaces make the wearer's own body intelligent and augmented. Overall, body movements can be classified into micro-movements (eye movement, facial expression, and the contraction \ expansion of muscles) and macro- movements (bipedal locomotion, arm/hand movement, and gestures) [24]. Furthermore, according to their function, the muscles of the face, which are micro-movements, are divided into two groups: mastication muscles and expressive or "mimitic" muscles. Unlike other skeletal muscles attached to the bones, facial expressions are caused by the movement of the mimitic muscles attached to the skin and fascia in the face. This group of muscles moves the skin, creating lines, folds, and wrinkles, causing the movement of facial features, such as mouth and eyebrows [25]. When strategically placed on these muscles, FX e-makeup sensors act as switches. Humans use a wide variety of muscles for creating gestures, which are macro-movements. When we initiate a voluntary movement, the brain sends an electrochemical signal that traverses our nervous system through the spinal cord and eventually arrives at the motor neurons. These neurons stimulate our muscles causing movement or force. Several sensors are used on wearables to capture movements and other biodata. For example, EMG (electromyogram) detects muscular movements by gel-based sensors firmly held in place with adhesives and accelerators on different parts of the body to detect body posture and movements. New Beauty Technologies may be created around other body movements and extended by other sensors and actuators [26].

### 3.3. Cosmetic Computing

Unlike modern traditional cosmetics, beauty wearable devices are a creative beauty technology that can empower individuals with more personal, playful, and performative abilities. Beauty wearable devices provide an interesting opportunity to marry function and form through design and creation. This process is defined as cosmetic computing, a vociferous expression of radical individuality and an opportunity for deviance from binary gender norms. It is a catalyst towards an open, playful, and creative expression of individuality through wearable technologies. It is a liberation call across genders, races, and body types. It is a new-wearable that leveraging the term "cosmetics", originally meaning "technique of dress". Cosmetic computing that integrates with fashionable materials and overlays applied directly to the body or its appendages can empower individuals towards novel explorations of body and self-expression. Cosmetic computing differs in its pivoting away from engaging directly with "beauty" as a theme. This emerging area uses the already culturally accepted practices, such as makeup, temporary tattoos, and artificial fingernails as sites for technology. It also provides an entry point for nontechnical hobbyists to get involved with the design and creation of wearable devices. We expand this vocabulary of on skin wearable devices with new capabilities, such as a dynamic display with no internal power supply [27]. This opens up an interaction space for new and largely unexplored aesthetic expressions.

### 3.4. Living Makeup

Drawing on a face, in the form of "make-up", represents an important element of entertainment. Although such drawing has traditionally relied on the physical application of paint, it is possible to map digital textures to the face using a combination of video projection and face tracking technologies [28]. Applying these approaches to physical faces through projection has great potential for a variety of applications. Furthermore, the possibility of projection onto arbitrarily moving faces can greatly influence the future projection mapping application on stage, as well as in film and art makeup industries. Definitely, the appearance alteration is traditionally static and requires manual labor to be changed. The digital era has given rise to the emergence of new opportunities in this context, and projection-based non-rigid expressive augmentation has the potential to give rise to a large variety of new creative application scenarios in the future. Therefore, it is expected that it will show a live makeup that includes futuristic and abstract visuals that deviate from the traditional makeup method.

## 4. CONCLUSIONS

Beauty technology, which observes and uses the human body from multiple perspectives, has become the basis for case studies in computing, chemistry, biology, body structure, human behavior, electronics, and design, and so forth. In the present paper, we reviewed available case studies on this topic. Our results suggest the following conclusions.

First, conductive materials is interactive materials that integrate with the body by embedding technology into beauty products based on RFID tags, conductive inks, thermochromic pigments, small magnets, conductive nail polish, conductive artificial hair, and other new materials. Using these materials makes it possible to create seamless devices that integrate with the body by embedding technology into beauty products such as makeup, skin prostheses, artificial nails, and hair extensions. The use of these materials also enables a range of applications in beauty technology.

Second, it is necessary to understand the body movements such as facial expressions occurring in muscles, the properties, structures, and human body functions of the skin and its appendages. Such understanding plays a crucial role in the on-body interaction of beauty technology that physically blends into the body. The human body can detect information in personal space and use it as an input for wearable devices. Furthermore, beauty technology can be extended with human-computer interaction as an interactive surface for mobile computing.

Third, beauty wearable devices are removable, futuristic body-worn displays attached to the body to interact with the digital world. Beauty wearable devices belong to cosmetic computing, a concept that expands the vocabulary of on-skin wearable devices. It is integrated with fashionable materials and overlays applied directly to the body or its appendages. It is a creative beauty technology for a new aesthetic expression of the body attachment method as a dynamic display with no internal power supply.

Fourth, live makeup based on projection mapping is a method of non-rigid expressive augmentation. It is possible to map digital textures to the face using a combination of video projection and face tracking technologies. Applying these approaches to physical faces through projection can greatly influence the future projection mapping application on stage, as well as in film and art makeup.

Aesthetics is an important design consideration for beauty technology. Therefore, we envision that the beauty industry will contribute to this wave, art, and science form a mutual relationship, and various new creative beauty technologies have a great potential of the beauty and art industries.

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