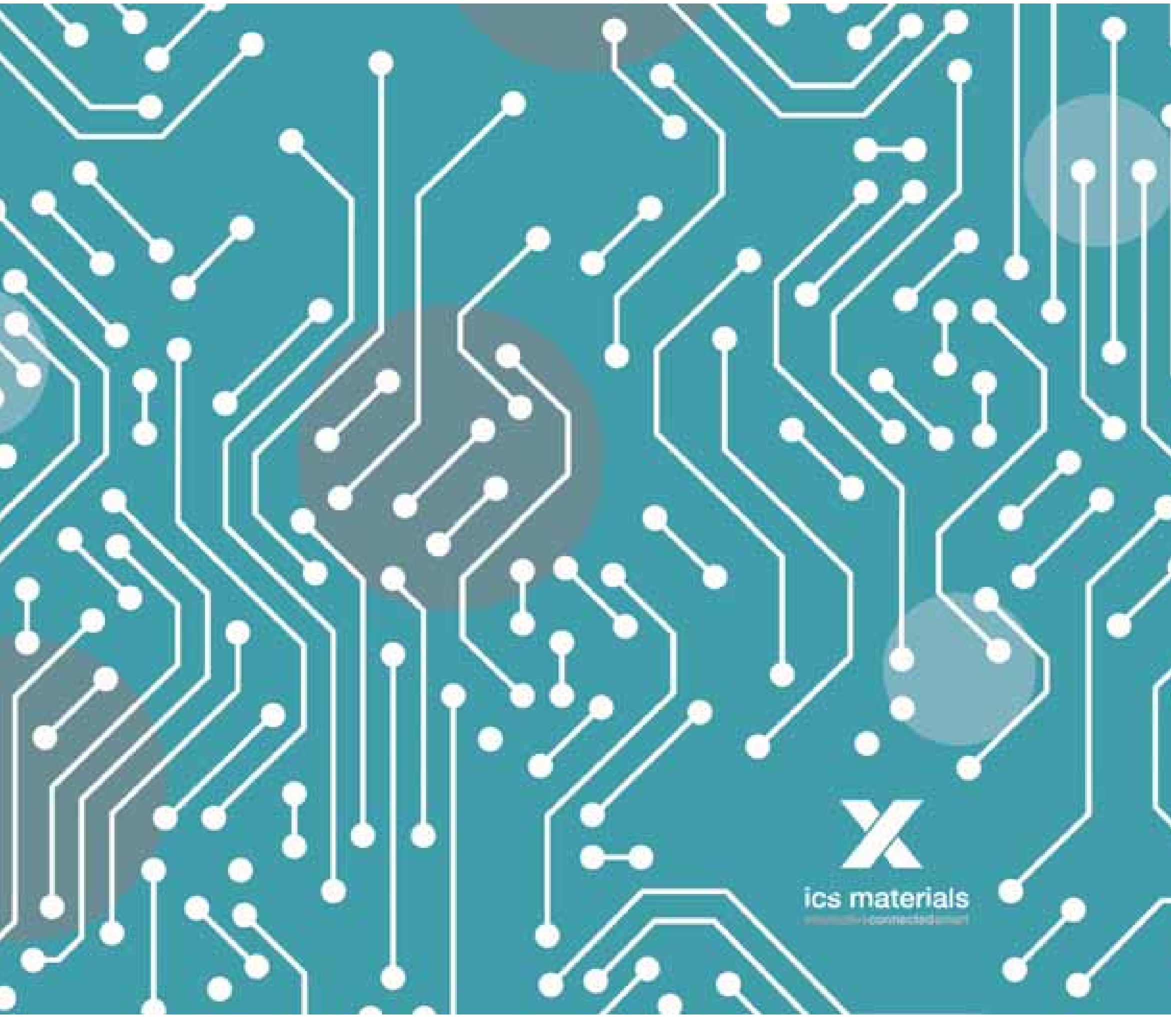
ICS MATERIALS

Interactive, connected, and smart materials

edited by Valentina Rognoli and Venere Ferraro



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3. Smart Products & ICS Materials

by *Ilaria Vitali, Erika Arcari* and *Venanzio Arquilla*
Politecnico di Milano, Department of Design

In this chapter, we use the term smart with a slightly different meaning, this time not referred to smart materials, but to smart products that incorporate IT technologies. The objective of this chapter is twofold: first, we want to give an overview of the concept of product smartness and smart products, then we reflect on the relationship between smart product and ICS materials.

While smart products are a product category that represents networked consumer electronics, the concept of product smartness is broader and defined by two main dimensions, one more technical, and the other more linked with user perception.

This chapter is an opportunity to reflect on the role of ICS materials -materials that are advanced, interactive and technological - in the development and design of smart connected products.

This arises important questions such as: do smart products embed smart materials and ICS materials? What are the limits and opportunities for their application?

The considerations in this chapter come from the authors' professional and academic research, which deals with the design of meaningful smart products and of conversational products, envisioning possible new opportunities and potential threats.

Keywords: Smart Products, ICS materials, Smartness

1. The concept of Smartness

The term "Smart" has multiple meanings and can be referred to people, materials, devices, systems and more.

A material is smart or intelligent/responsive when one or more of its properties can be controlled and significantly changed in a reversible way (Spaggiari et al., 2019). Then, when a product can be defined as smart?

Generally, the term is used to identify those products that become intelligent through embedded processing capabilities and the use of IT technologies.

Smart products are a product category that represents internet-connected consumer electronics that embed computational intelligence. Other terms such as intelligent products, connected products or smart things have been used to describe the same concept (Kiritsis, 2011) and refer to various technological paradigms such as Internet of Things, Ambient Intelligence (Aarts & De Ruyter, 2009), Ubiquitous Computing and Pervasive computing.

While an agreed univocal definition of "smart product" does not exist, it is possible to identify which are the characteristics that these types of products should have to be named "smart".

The concept of product smartness has two principal dimensions: the first one is the technical dimension, in which we find technical specifications or requirements that the product should have; the second one is the perceptive dimension, in which can be identified those characteristics that users perceive as smart (Rijsdijk & Hultink, 2009).

2. Technical dimension of product smartness

There are different definitions of "smart products". They can be defined as those objects that can use information about themselves and about the environment in which they run, and that can interoperate with other products (Gutierrez et al., 2013).

From a more technical point of view, they can be defined as products with embedded IT technologies, generally connected to other devices or networks, and with incorporated microprocessors, sensors and actuators, in order to obtain some benefits for the end-user: control over the performance, enhanced product features, function and capabilities (Dhebar, 1996).

There are three common characteristics that smart products share: they are cyber-physical, networked and embed computational intelligence (Vitali & Arquilla, 2019).

Smart products are **cyber-physical** (Abramovici, 2014), or **phygital** because they blend hardware and software. They are physical objects with digital representation, and interaction can occur through multiple, multimodal interfaces.

Smart products are **networked** and part of a larger network of things, people and services. Connectivity enables them to communicate with users and other objects, and can happen in different forms: one-to-one connection, one-to-many, many-to-many (Porter & Heppelmann, 2014).

Smart products **embed computational intelligence** and display forms of autonomous and proactive behaviours (Gutierrez et al., 2014; Rijsdijk & Hultink, 2009; Abramovici, 2014; Maass, Filler & Janzen, 2007; Mühlhäuser, 2017). Computational intelligence enables them to be context-aware, perceiving information about its use and environment, adapting and personalizing their behaviour. They are more proactive and can anticipate the user's intentions (Maass et al., 2007).

Connectivity and computational intelligence allow data to be exchanged between different products and enables some of their functions to exist outside the physical device (Maass et al., 2007) such as monitoring the product's conditions, its external environment, and its operations and usage; control various functions as well as to personalize the user experience.

As already mentioned, the other dimension of smartness beyond the technical aspects is the perceptive dimension: what people perceive as smart?

3. Perceptive dimension of product smartness

The smartness of a product perceived by a user is described as a construct of seven dimensions identified by Rijsdijk & Hultink (2009).

These dimensions are: autonomy, adaptability, reactivity, multi-functionality, ability to cooperate, human-like interaction and personality.

Smart products usually possess one or more of these dimensions. However, these functionalities must be obtained using Information Technologies (IT) for the product to be described as "smart". The degree of smartness depends on the degree they possess these different dimensions, and with what extent (low, medium, high).

Autonomy is possessed by those products that can, to a certain extent, operate independently without the need for user intervention.

Adaptability and reactivity are two similar but different concepts. A reactive product can directly respond to stimuli; for example, it perceives a change in the environment through a sensor and signals the users. An adaptive one, can react and adapt behaviors over time: for example, a screen with adaptive brightness reacts to the light but also remembers what are the user's preferences in that situation.

Multifunctionality is another quality that users perceive as smart: products that can perform multiple functions are seen as smarter and more advanced. So are products that can cooperate and are compatible with other services and devices. Compatibility is a crucial characteristic for networked products, since being part of an ecosystem makes them more competitive in the market (Agrò, 2018).

In the research of Rijsdijk & Hultink also emerged that products that recreate a humanlike interaction and have a personality are perceived as smarter. For humanlike interaction, they refer to the degree to which a product can communicate and interact in a human-friendly, natural way. Personality instead refers to the smart product's ability to possess a credible character, with believable personality and emotional state. This is particularly evident in products that embed conversational user interfaces (CUI), such as virtual assistants (VPA) like Alexa and Google Assistant (Vitali & Arquilla, 2019).

4. Smart products and ICS Materials

Materiality impacts the experience with products. The interest to develop a new generation of interactive materials to produce smart products is arising, and those interactive materials can be identified as ICS materials (Parisi et al., 2018 A/B).

ICS is an acronym for Interactive, Connected and Smart materials, and identifies those materials that, by operating new and complex functions, can provide an interactive, connective and smart material experience (Ferrara et al., 2018). ICS materials can "feel" and react to external stimuli with specific behaviours. They can be defined as composite entities in which artificial intelligence and materiality are combined (Ferrara et al., 2018).

ICS materials are characterized by the reciprocity of action and reaction with users/environments; variability of properties so that the reaction is reversible and contextual; they can be programmed (not only via software) and connected to establish a two-way exchange data (not only via network). These characteristics can be achieved through electronic, chemical, mechanical and biological means.

An ICS Material is not necessarily an original material that integrates all the features described in the definition (Ferrara et al., 2018), but it can be considered akin to a technological component with programmable behaviour.

Materials have different degrees of smartness. Parisi et al. (2018-B) propose a map for ICS materials that consider their degree of interactivity, smartness and complexity, and divides materials in inactive, reactive and proactive materials. Reactive materials include smart materials that can reversibly change features in response to specific stimuli.

Proactive materials are closer to the concept of ICS materials: represent a combination of inactive or reactive materials with embedded electronic components in the form of sensors and actuators, connected with external or embedded computers.

Despite the technological availability and the increased rage of interactive materials, their possible applications in electronic goods are still to be fully understood (Coelho et al., 2009; Parisi et al., 2018-A; Razzaque et al., 2013; Vallgårda et al., 2016). Examples on a wide scale are missing, so there is still space to reflect on ICS materials and their applications.

5. Are Smart products using ICS Materials?

Looking at the consumer electronics market, it is possible to categorize smart products into three macro-categories (Vitali, Arquilla & Rifino, 2019).

1. In the first case, the smart product is the technological and connected version of an existing analogue artefact. For example, a smart vase that can monitor a plant's needs and water level.
2. In the second case, the object is defined smart because it is a more advanced, connected version of an existing electronic/digital product. For example, a smart washing machine that can be controlled through an application.
3. In the last case, the object is smart because it is a combination of new and existing functions that create a new product category. An example is the Roomba vacuum cleaner, that combines robotics and vacuum cleaning.

All these products are considered smart for their technological performance, and because they embed electronics components and IT technologies.

As previously said, in the consumer electronics market, the suffix "smart" is used in close relationship with technology, rather than for the use of smart materials. It is rare to see a technological product defined as smart because it uses smart material.

For example, if we think of a "smart bottle", we would probably imagine a product that quantifies how much water is consumed, or that can change or maintain a set temperature, or that processes the liquid inside. Therefore, it would be considered smart because of its technological value. In the consumer market, a bottle that uses an advanced super-hydrophobic nano-coating to let the liquid inside slide without sticking to the surface wouldn't probably be defined as a smart product.

Currently, it is hard to say that smart products embed ICS materials. This because it may not be easy to differentiate between an ICS material and a standard electronic component embedded in a material.

For example, let's imagine a smart product that integrates a touch display or capacitive sensor, hidden behind a material so that it seems embedded in the surface. The result will be interactive, yet with specific limited dimensions, and the different components are not fused in a material, they maintain their materiality. Is it considered an ICS material?

The boundary between electronic components and ICS material is not clearly defined.

Moreover, it may be possible that ICS materials are used in a product, but it is not evident to the final consumer because they provide a feature that is not visible.

One example is when a product embeds in-mould electronics (Fig. 1). With in-mould electronics, a flexible circuit is encapsulated in an injection-moulded plastic part. This part could be used for control panels and interactive controls for appliances and broad surfaces such as automobile control panels.

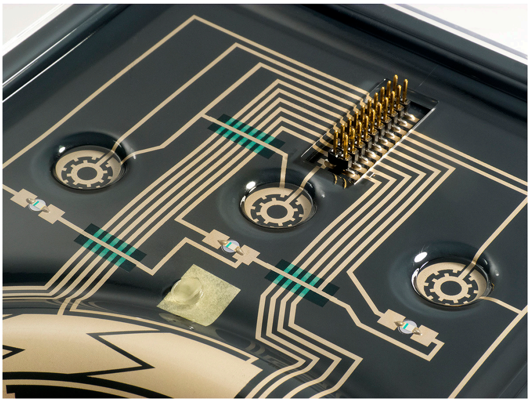

Fig. 1 - Example of in-mould electronic by DuPont, TactoTek https://www.designnews.com/thermoforming/dupont-tactotek-ratchet-mold-electronics-efforts/176641071057057

This technology, and printed circuits in general, enable to produce compact products, with less thickness and dimensions.

Their use can have an impact on the shape of the product but may not affect the experience of the end-user.

This may be different in the case of wearables and products that have to be worn on the body. In this situation, printing the circuit on a flexible media, or relying on sensors infused in textiles or other media can positively improve user comfort.

6. Limits and opportunities of ICS materials for Smart products

Previously we discussed about Smartness and Smart products; we briefly defined what ICS materials are and made considerations on their applications in the consumer market. This section reflects on what are possible limits and opportunities of ICS materials for smart products. It mainly focuses on manufacturing, upgradeability, and scale of application.

Launching a smart product on the market is an action with a significant impact on a company (Porter & Heppelmann 2014). This because smart products follow a development that is more similar to software than hardware. A smart product has to be updated in time and needs to be supported by a reliable infrastructure, both in terms of technology and service providing.

The smart product uses different technologies such as hardware, software, communications, and cloud platforms/applications.

The manufacturing phase is a crucial moment in their development. To be economically feasible, they employ mass-produced, standardized components to limit the manufacturing price. This is a barrier to the use of more innovative materials and components: if a company doesn't have a structure to support the development of innovative technology, it has to rely on more standard parts.

Smart materials and more advanced ICS materials are often deepened in experimental studies or research products. This is a limit for a broader application in products for the consumer market.

Until those material doesn't become more standardized and available, not all companies could access them.

What are their technical characteristics? How do they enter in the existing production chain? How much do they cost? What are the benefits compared to a more standard component?

These are all questions that need to be strategically evaluated because innovating involves risks. In particular, innovative materials should guarantee lasting, reproducible, and controlled performance over time.

Curved smartphone screens are an example of the risks of innovating through ICS materials. Samsung was the first to launch on the market a smartphone with a foldable screen, but unfortunately, the first version had to be withdrawn from the market. This because the screen had structural problems and was easily worn or damaged, also because the beta users were convinced that they had to remove a film that was instead part of the screen structure (Fig. 2).

Fig. 2 - Samsung curved screen, damaged. https://www.businessinsider.com/samsung-galaxy-fold-mess-explained-2019-4?IR=T#6-but-just-days-later-review-units-started-failing-for-a-variety-of-different-reasons-6

For a brand, developing a proprietary ICS material bay be a strategic move to be competitive and recognizable on the market.

For example, LG invested in flexible OLED panels and produces them also for custom applications. In this way, the ICS material becomes standardized and cost-effective, thus desirable for consumer electronics producers.

Upgradeability is another limit to the use of ICS materials for smart products. Smart products are "never closed", and they can be updated during their whole life cycle. Through software updates, an existing connected product can offer new functionalities to its users.

Even though the digital/software component is relatively easy to upgrade, the hardware component represents a harder challenge, because it is not easy to remove and modify after the product purchase.

The problem of obsolescence between the hardware and software components shortens the life cycle of the product. For instance, a working smart product that has compatibility issues and that doesn't support your smartphone anymore, suddenly becomes "old", and its life cycle ends. This situation may also depend from the use of obsolete hardware components. Therefore, if we embed electronic components in artefacts that have a longer life cycle, such as furniture, we need to consider the problem of obsolescence from the start, designing for upgradability.

One good example was Nest, the smart thermostat now produced by Google: when was launched on the market it embedded some sensors that weren't even connected and used. This because they were activated later in time, in another update, to provide new functionality.

Using IT and interactive components that are embedded in materials can provide a challenge to tackle the problem of hardware/software upgradeability and obsolescence.

ICS materials can represent a good opportunity in specific scales of applications, especially for extra-small and extra-big formats.

On a traditional medium-to-small scale there are numerous standard components or strategies that can be used to exchange information, communicate, interact etc. For example, a LED that transmits feedbacks, a cap sense to make a capacitive button, are all standard components available at a low price and easy to control.

However, those components may have technical limits in case of miniaturization, and of economic limitations in case of bigger sizes of application. Therefore, ICS materials could be an exciting opportunity where conventional electronic solutions are not effective.

Technology infused in materials can bring to a significant reduction in product size, and open to new possibilities, mainly if they can operate without the need for batteries. One interesting example are debit cards that embed fingerprint sensors to authorize payment.

At the same time, ICS materials could be useful in other formats such as at the architectural level, to build interactive solutions that are more economically feasible and sustainable.

7. Conclusions

This chapter collects initial reflections on the relationship between smart products and ICS materials. After analyzing the concept of smartness and intelligent products, we include considerations on the possible limits and opportunities of the application of ICS materials.

Further clarifications need to be made to define more clearly what are the boundaries between ICS materials and embedded technological components. Interactive, Connected, Smart materials are an opportunity that needs to be formalized for a widespread application in the consumer electronics sector. They are still in the experimental stage, and their real availability is often still far enough from the actual market. When developed, they can become strategic elements to increase brand recognition and reputation.

Manufacturing and standardization in specific production chains is probably their hardest challenge, while they offer interesting opportunities in extra-small and extra-large scales of applications.

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Valentina Rognoli is associate professor in the Department of Design at Politecnico di Milano. She is a pioneer in the field of materials experience, starting almost twenty years ago and has established internationally recognized expertise on the topic both in research and education. Her mission is raising sensibility and making professional designers and future designers conscious of the infinite potential of materials and processes. The investigations of her research group focus on pioneering and challenging topics including: DIY-materials for social innovation and sustainability; bio and circular materials; urban materials and materials from waste and food waste; materials for interactions and IoT (ICS Materials); speculative materials; tinkering with materials; materials driven design method; CMF design; emerging materials experiences; and material education in the field of design. Since 2015, Valentina jointly leads, with Elvin Karana, the international research group Materials Experience Lab. She participates as principal investigator in the European Project Made, co-funded by the Creative Europe Program of The European Union, which aims to boost talents towards circular economies across Europe. Valentina is the author of over 50 publications. She has organized international workshops and events and has contributed as an invited speaker and reviewer for relevant journals and international conferences.

Davide Spallazzo, PhD in Design, is assistant professor at the Department of Design of Politecnico di Milano. Active in the field of Interaction Design and HCI, his research focuses mostly on design-driven and technology-supported approaches to valorize cultural heritage sites. Over the years, he took part in several national and international research projects dealing with mobile devices and mobile gaming dynamics to enhance the cultural visits' experience maximizing learning and social engagement, tangible and embodied interaction. His teaching activity is carried out in the field of Design both at Bachelor and Master level.

Vasiliki Tsaknaki is an assistant professor in Interaction Design at the IT University of Copenhagen, working in the Digital Design department and in the AIR Lab. Her research combines affective and bodily engagements with technologies, materials experiences, computational crafts and soma design methods in HCI. Through design studies she investigates and reflects on intersections of these areas with a critical view on bodies, technological values and data. She has a PhD in Interaction Design from KTH Royal Institute of Technology in Stockholm, Sweden, on the topic of crafting precious interactions.

Ilaria Vitali is a product designer and PhD candidate at Politecnico di Milano who graduated with a Master's degree in Product Design for Innovation and a dual honors degree from Alta Scuola Politecnica. Her research focuses on smart connected products and devices with conversational interfaces and explores how to design them, creating guidelines and tools for didactic and professional activities. In particular, she developed the Mapping the IoT Toolkit (mappingtheiot.polimi.it), an accessible kit to aid in the design of IoT devices.

This present book covers a series of outstanding reputation researchers' contributions on the topic of ICS Materials: a new class of emerging materials with properties and qualities concerning interactivity, connectivity and intelligence. In the general framework of **ICS Materials**' domain, each chapter deals with a specific aspect following the characteristic perspective of each researcher. As result, methods, tools, guidelines emerged that are relevant and applicable to several contexts such as product, interaction design, materials science and many more.

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