

Design for Next... Year. The Challenge of Designing for Material Change

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Abstract: From the moment of purchase, pristine objects are subjected to an array of stimuli including wear, impact, heat, light, water and air which alter their tactile and aesthetic properties. Material change is often regarded as ‘damage’ or ‘degradation’, but has potential to be used as a tool to engender emotional engagement to an object. We present a framework for designers to better understand how materials change with use, and in turn how people respond to materials as they change. Key challenges are identified which must be overcome to use this framework in design practice – people’s physical interaction with objects is poorly understood, it is difficult to simulate material change, materials resources for designers do not provide information about material change, and people’s responses to aged materials depend on a complex web of interacting factors.

Keywords: material change, cosmetic obsolescence, degradation, patina, graceful ageing

1. Introduction

Materials change.

“...the formal language of design has notably shifted to a space dominated by the smooth and opaque surface. Such impenetrable surfaces make it easy to forget that the materials from which it was made are kinetic, that it is their ‘will’ to decay or change state” (Carr & Gibson, 2015).

The response of materials to environmental stimulus, such as air, water and touch, is usually referred to as ‘ageing’, which suggests that materials alter with time (Nobels, Ostuzzi, Levi, Rognoli, & Detand, 2015). However, it is not time, but a complex interaction of physical, chemical and biological processes which result in changes to a material surface. To acknowledge this, we refer to these processes as ‘material change’.

The process of material selection is usually focused on the pristine object that entices the purchaser, but from the moment of purchase the surface of an object changes in response to use and interaction with its environment: “Industrial design usually produces objects to be used in the future,

but rarely investigates how these objects will change in time” (Nobels et al., 2015). Delight at the untouched, often shiny, appearance of new products which “invites sensual engagement” (Maffei & Fisher, 2013, p. 231) can rapidly change to dis-satisfaction with ‘worn’ or ‘aged’ materials which, coupled with persuasive advertising, drives the cycle of replacement of products which are still fully functional (Nobels et al., 2015; Woolley, 2003). Material change is commonly perceived as damage or degradation, and for many types of product ‘cosmetic obsolescence’ contributes to premature disposal and unsustainably short product lifetimes (Cooper, 2005; Lilley, Smalley, Bridgens, Wilson, & Balasundaram, 2016; A.H.G. Manley, D. Lilley, & K. Hurn, 2015b; Packard, 1963).

“Many objects lose value in time because they lose newness, which is the attractive factor in the purchase phase. Newness is a complex mixture of different sensorial properties like odour, shiny colour and the integrity of surfaces.” (Nobels et al., 2015).

Whilst ‘graceful ageing’ of material surfaces is a potential strategy for creating enduring products, emotional attachment is difficult to predict and often elusive (Connor-Crabb, Miller, & Chapman, 2016; Cooper, 2005; Tasaki, 1992). “Objects capable of sustaining long-lasting relationships with consumers are rare” (Chapman, 2005, p. 66) due to unreasonably high expectations and rapid ‘acclimatization’ and loss of novelty. In this paper we ask: with a better understanding of material change and how it is perceived, could product lifetimes be extended by designing for positive experiences of material change through the life of a product?

This paper explores how aesthetic changes to the surface of a material are perceived, and how material change could be more widely utilised as a design tool. A complex web of factors is identified, including material type and surface finish, product context, rates of change, initial perfection or variability, cultural context and individual preference, which all combine to define the elusive difference between wear, degradation and ‘graceful ageing’. Strategies to increase the likelihood of material change being perceived positively are explored - from engineering surfaces which ‘age spectacularly’, to careful integration of material selection with other design decisions to influence how an object is used and maintained.

In conclusion, the considerable challenges which must be overcome to enable ‘design for graceful ageing’ are identified. Results of a user study show that it is not well understood how people interact with their possessions and how this interaction impacts the object’s surface. Physical test methods cannot currently simulate material use and ageing - making material evaluation and development difficult. Material resources for designers present materials in their pristine state with virtually no information about aesthetic change in use.

2. A framework for designing with material change

An understanding of material ‘durability’, i.e. how a material changes in response to a wide range of physical, chemical and biological stimuli, is a vital first step in understanding how material change will influence the lifespan of a product. But this is not enough: “It is important to note here that patina is not an issue to do with material resilience or durability, but rather, a societal preoccupation with what an appropriate condition is for certain typologies of material and objects to be in” (Chapman, 2013, p. 141). We propose that a complex web of factors must be considered which require a multi-disciplinary approach to understand the interaction of material type and surface finish, product context, rates of change, initial perfection or variability, cultural context and individual preference, which all combine to define the elusive difference between degradation and ‘graceful ageing’. The interaction of these factors is summarised in Figure 1.

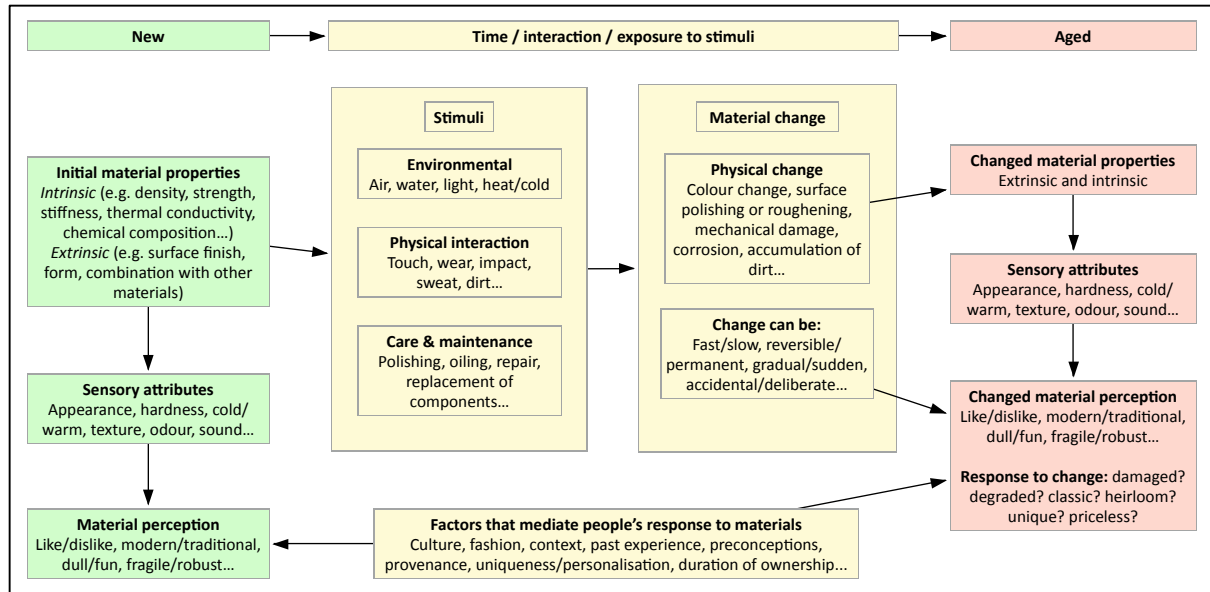


Figure 1. Framework for understanding material change in product design, showing interaction of material type, intrinsic and extrinsic properties, stimuli, and physical material changes, and experiential responses to those changes.

2.1 Properties and perceptions of new materials and objects

The left-hand side of the framework (Figure 1) describes the properties of the new material as specified by the designer. These include both intrinsic properties of the material itself (well defined engineering properties such as strength and thermal conductivity) and extrinsic properties which depend on the application of the material, such as the shape, thickness and surface finish. Whilst objects are primarily experienced by sight and touch, we must not neglect the other senses, in particular smell which adds to the perceived 'newness' of an object (Woolley, 2003). These material properties can be quite easily mapped onto sensory attributes of the object: what does it look like? How does it feel? What does it smell like? What sound does it make? Ashby and Johnson (2013) calculate several 'aesthetic attributes' by combining well defined engineering properties, for example "softness (to the touch) = stiffness \times hardness" (p.218).

The difficult step is to move from these sensory attributes to how the material is perceived – how do these sensory stimuli make people feel? This emotional response to materials is often described using word pairs such as like/dislike, modern/traditional, dull/fun and so on. To understand material perception, studies have been carried on small swatches of material (e.g. Chen, Barnes, Childs, Henson, & Shao, 2009; Overvliet, Karana, & Soto-Faraco, 2016; Zuo, Jones, Hope, & Jones, 2016), yet this ignores the fact that people experience materials within a particular physical, social and cultural context. These complex influences on material perception are addressed in Step 1 of Elvin Karana, Barati, Rognoli, and Zeeuw Van Der Laan (2015)'s 'Material Driven Design' methodology, described as 'Experiential Characterisation of the Material' which advocates consideration of sensorial, interpretive, affective and performative material experience. There are many diverse, interacting factors which mediate people's response to a material, including the product context (function, cost, provenance, duration of ownership, personalisation) and the owner's preconceptions, past experiences and cultural influences (e.g. Fisher, 2004; E Karana, 2004; Tasaki, 1992; van Kesteren & Stappers, 2005).

This provides the starting point: a material, combined with other materials and formed into an object, which elicits a certain response in a certain person at a certain time.

2.2 Material change: stimuli & processes of change

From the moment of purchase a complex interaction of physical, chemical and biological processes result in changes to material surfaces. As we move right across Figure 1 we introduce material change. Again, we can follow a process of understanding the physical changes in the material (well defined engineering), how this changes the object's sensory attributes (closely based on the modified physical properties of the material), and finally the much more complex question of how people's response to the material alters following this material change. Before we can assess how the material changes, we need to understand the stimuli driving those changes, which can be divided into three categories: physical interaction; environmental; and care, maintenance and repair.

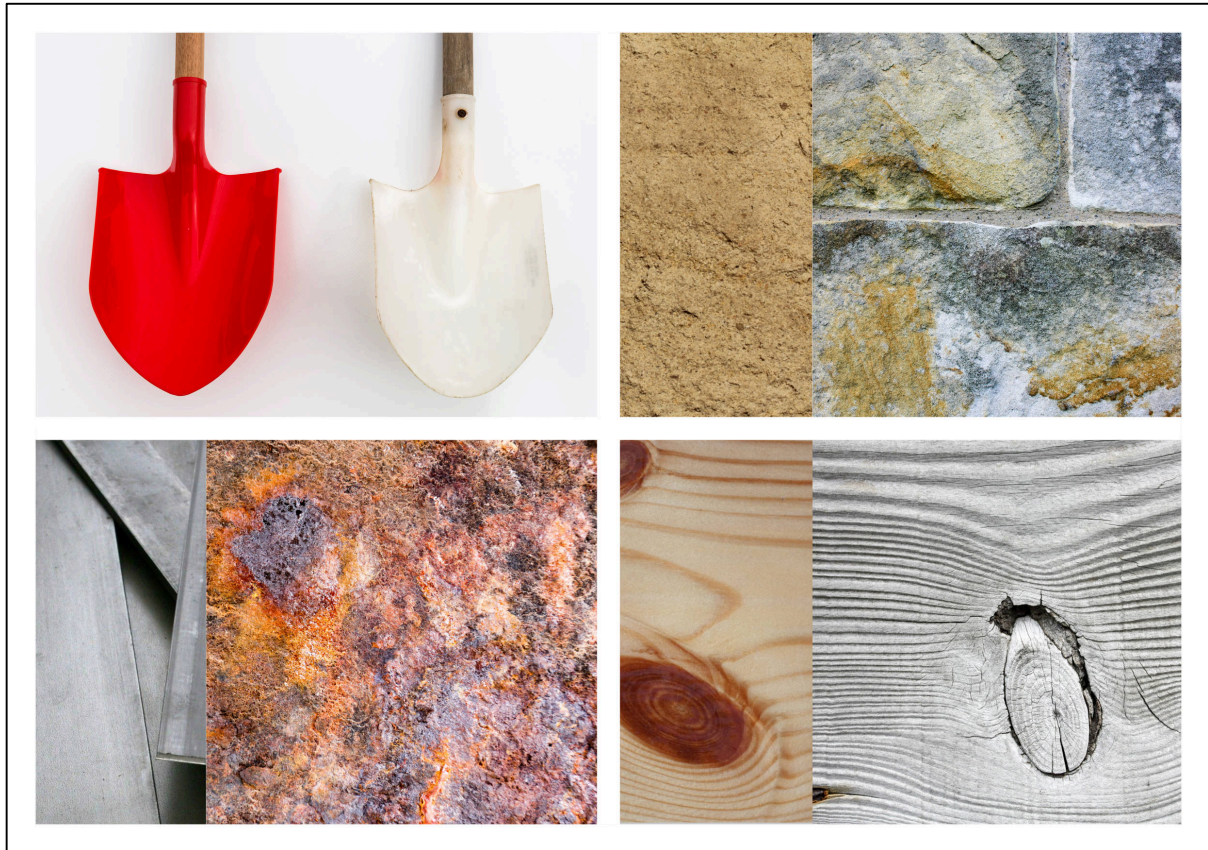


Figure 2. Materials change (clockwise from top left): a plastic spade is severely faded by sunlight (despite it being designed for outdoor use); sandstone develops a rich patina of lichen; wood has lost colour but the surface texture is accentuated after exposure to sunlight and salt from the sea; mild steel reacts with oxygen and water to produce beautiful but fragile rust. In each case the new material is on the left. Except for the spade, the new and old materials are similar but not identical samples.

Environmental stimuli include moisture, light, temperature, growth of mould and fungi, and reaction with oxygen and other chemicals in the atmosphere (Figure 2). Exposure to these stimuli can be quite easily predicted depending on the type of product: will it be used indoors or outdoors? will it be used in a wet environment? Different stimuli are important for each class of material: metals oxidise, plastics degrade when exposed to ultraviolet light, wood decomposes in response to UV and is prone to fungal growth. Beyond these broad generalisations, individual types and grades of material respond differently. Oxidation of metals can result in flaking rust on steel, or a hard wearing and aesthetically pleasing green patina on copper. Ultraviolet light damages the structure of wood, but in doing so accentuates the surface texture and grain pattern, with the end results dependent on species, cut, exposure to moisture, and any surface treatments.

Physical interaction includes handling, carrying and dropping an object. The conclusion of a recent user study by the authors was clear – we do not understand how people physically interact with their possessions, and there is a dearth of literature on this subject (refer to Section 3.2 for details). The highly variable effect of physical interaction with an object is referred to as ‘wear and tear’, which covers a range of surface changes described by A.H.G. Manley, D. Lilley, and K. Hurn (2015a)’s ‘Taxonomy of Damage’ - impact, ablation (chipping of the surface), abrasion (scratching and polishing) and accumulated dirt.

Whether owners engage with care, maintenance and repair of an object varies dramatically depending on the individual’s attitude and skills, and the product type, age, provenance, value, and the materials from which it is made (Gregson, Metcalfe, & Crewe, 2009; G Salvia, 2015), and provides the opportunity to go beyond passive consumption to a “highly productive and creative appropriation of those goods which transformed them over time” (Tilley, Keane, Kuchler, Rowlands, & Spyer, 2006, p. 348). In Western cultures repair is usually carried out with the aim of making the object ‘as good as new’, in contrast the Japanese art of Kintsugi (“golden joinery”) which celebrates the repair and makes the breakage part of the history of the object (Keulemans, 2016). Recently this has been paralleled in the West by ‘Sugru’ (<https://sugru.com>) - a brightly coloured product which enables highly functional, but also ostentatious, repairs and modifications to be made to a wide range of materials. Care and maintenance, such as oiling wood or leather and cleaning and polishing metals or painted surfaces, strongly influences the process of material change. Designers can influence this process by making care and maintenance an inherent part of the use of the object (e.g. wooden salad spoons which are oiled by being used to serve salad), or by providing instructions and materials, but the level of care will clearly be a source of great potential variability in the life of the object.

2.3 Properties and perceptions of ‘changed’ materials and objects

A combination of material changes, interwoven over time, combine to create a surface ‘patina’ that discloses the life of an object (Baxter, Aurisicchio, & Childs, 2016; DeSilvey, 2006; Giaccardi, Karana, Robbins, & D’Olivo, 2014). There is a dichotomy in how this patina is interpreted; it can result in dissatisfaction or allow an emotional bond to be forged with the object. Many interacting factors mediate this response including the type of material, product context, cultural influences, the rate at which the material changes, duration of ownership, the provenance of the object, and whether the object has been cared for and maintained. Understanding these factors is vital to enable designers to create enduring (as opposed to durable) objects:

“Some materials ‘degrade’ while others ‘mature’ by maintaining or improving certain qualities. The positive term of maturity is usually used for natural materials such as stone, paper, wood, and leather, which over the years can acquire scents, colours, and textures: characteristics that far from diminishing their quality, instead acquire an aura of antiquity and preciousness.” (Rognoli & Karana, 2014).

To understand people’s perception of a changing object, we must consider the initial condition of the object’s surface, and the changes to the surface relative to this initial state. Prior to the Industrial Revolution objects were hand crafted and irregularity and individuality were ubiquitous, described by Pye (1968) as ‘unregulated’ work. Mechanisation brought repeatability and highly ‘regulated’ work. Craftsmanship gave way to mass produced objects which strived for homogeneous, repeatable ‘perfection’ (Woolley, 2003). The usage of the words ‘perfect’ and ‘imperfect’ in English include an inherent value judgement. An ‘imperfection’ is defined as “a defect, fault, blemish” (Oxford English Dictionary, 2016), with perfection describing the absence of these features. The word ‘perfection’ derives from the Latin *perficere* ‘to complete’, with no preconception about what completed state

the maker is striving for. In contrast, some cultures treasure ‘imperfect’ objects: wabi-sabi is the “quintessential Japanese aesthetic... It is a beauty of things imperfect, impermanent, and incomplete” (Koren, 2008, p. 7) and celebrates simplicity, uniqueness and change.

Natural materials, with their inherent variability, surface complexity, and resilience (Hoadley, 2000; Pye, 1968), avoid a clear distinction between ‘shiny and new’ and ‘worn’, reducing the likelihood of short term dis-satisfaction (Lilley et al., 2016) (B. Bridgens, Lilley, Smalley, & Balasundaram, 2015). In stark contrast, in our “scratch-free world of slick polymers” (Chapman, 2013, p. 141) any change to a man-made material surface, such as inevitable abrasion or scratching, is commonly interpreted as damage which can result in dissatisfaction and drive the cycle of premature replacement. Ageing or ‘decay’ of most plastics involves both aesthetic and functional degradation: fading colours, yellowing, scratched surfaces and embrittlement (Fisher, 2004; Shashoua, 2012). There is perhaps an expectation that man-made materials should be *designed* to remain pristine, whereas there is greater acceptance that natural materials will change:

“It is OK for wood to become old and dirty. You can’t blame it; it is its nature. But plastics were invented. So when they become ugly, when they melt or crack, you blame the inventors. They should have done a better job.” (Nobels et al., 2015).

Any consideration of materials alone is a generalisation, which must be refined by considering the role of the product context. A material that is obviously ‘worn’ can be a virtue (for example leather that has softened, conformed to the user, and changed in colour to acknowledge this change), although not to the extent of being ‘worn out’. Thus there exists a culturally situated phenomenon of ‘acceptable wear’ - or limits on the desirability of wear - in product materials (Pedgley, 2014). Scratching and wear to the surface of electronic devices is almost always seen as degradation, whereas ‘signs of use’ (Giuseppe Salvia, Ostuzzi, Rognoli, & Levi, 2010) or ‘traces of life’ (Elvin Karana, 2012) on sports equipment and musical instruments are seen as:

“a type of material history — in part procured a deeper sense of care and involvement between participants and their things by inscribing a unique and personal semantic narrative into the objects through material experiences of use” (Odom & Pierce, 2009, p. 3796).

The timing and severity of changes to an object’s surface strongly influence how that change is perceived, and this perception is also mediated by the type of stimulus. For ‘wear and tear’ or changes due to the object’s environment, a gradual, almost imperceptible transition of the surface, which starts a respectful time after purchase, is more likely to be perceived as a valuable patina. Sudden changes to an object’s surface, particularly accidental damage soon after purchase, will usually be regarded negatively: “...I’m pretty protective over it for the first couple of weeks and then after that you don’t really notice damage so much” (Manley et al., 2015b). However, if the stimulus for change is a notable event (for example particular use of a piece of sport’s equipment or tool) then sudden change may be more acceptable, as it builds a narrative about the object (Odom & Pierce, 2009).

For certain product types, material change results in an increase in monetary or emotional value for reasons which can be aesthetic (e.g. antique furniture, old stone paving), functional (shoes and clothing conforming to the user), or a combination of both. This increase in value is driven by scarcity and individuality. An important distinction must be drawn between private possessions and public property, which becomes increasingly relevant with the rise of the sharing economy. Desirable imperfection that has arisen through use, is less likely to be acceptable when it has arisen from other people’s use. Here the concept of ‘contaminated interaction’ becomes central (Baxter et al., 2016).

3. Challenges

To enable this 'framework for material change' (Figure 1) to be utilised by designers there are gaps in knowledge and understanding that must be addressed. Here we focus on two: the lack of educational resources to develop designer's understanding of material change and people's response to materials, and the lack of understanding of people's physical interaction with objects and hence the difficulty in simulating this interaction.

3.1 Materials resources for designers

A range of material selection resources are used both to educate design students, and to inform material selection in design practice (Akin & Pedgley, 2016; Sørensen, Jagtap, & Warell, 2016; van Kesteren, 2008). There are two distinct types of resource: online databases of material properties, and physical material libraries or collections. Online resources are widely accessible and provide extensive technical data (e.g. strength, stiffness, thermal conductivity and so on) (Figure 3). One major materials database (Granta CES, www.grantadesign.com) is currently evaluating a pre-release database which includes 'experiential' properties such as warmth, hardness & flexibility, but does not go beyond this to suggest how people might respond to these characteristics. Information on material change is limited to numerical durability ratings for different types of environmental exposure (eg. acid/alkali, fatigue, ultraviolet), focused on functional requirements with no consideration of aesthetic, tactile or experiential changes with use.

Physical collections of materials provide the benefit of being able to handle samples and experience their tactile and aesthetic properties. Materials are almost exclusively presented in pristine condition (Figure 3), or in fact a slightly modified (but unknown) state depending on how they have been handled, and the conditions in which they have been kept. The authors visited five materials libraries (Politecnico di Milano; SCIN, London, Central Saint Martins School of Art and Design, London; Rematerialise, Kingston University; Material Lab, London – *see acknowledgements for further details*) and found very limited reference to material change or ageing. Where 'aged' samples were presented there was no information about the stimuli required to effect that change. SCIN had observed that less durable material samples were changing in response to visitors handling them, and were concerned that they were presenting materials in an undefined state of 'ageing'. A recent review of 17 materials libraries worldwide did not mention material ageing as a feature of any the libraries studied (Akin & Pedgley, 2016).

In collaboration with the authors, SCIN surveyed 250 design professionals in September 2016 (predominately interior, product or industrial designers and architects) to ascertain their requirements for resources to support material specification. The survey findings clearly demonstrated demand for greater, more detailed guidance in physical and online libraries about tactile and aesthetic properties (74% and 68% of respondents respectively) and how materials change and age over time in response to use/wear (63%).

It could be argued that tacit knowledge built up from personal experience observing material change in a wide range of products equips designers to specify materials which will 'age' well in a particular application. This may be true for certain commonly used materials (e.g. ABS plastic, copper, oak, and so on), but tacit understanding is hampered by the complex web of factors that influence how a material will change in use, including the vast number of material variants and new materials, different surface finishes, different manufacturing processes and so on.

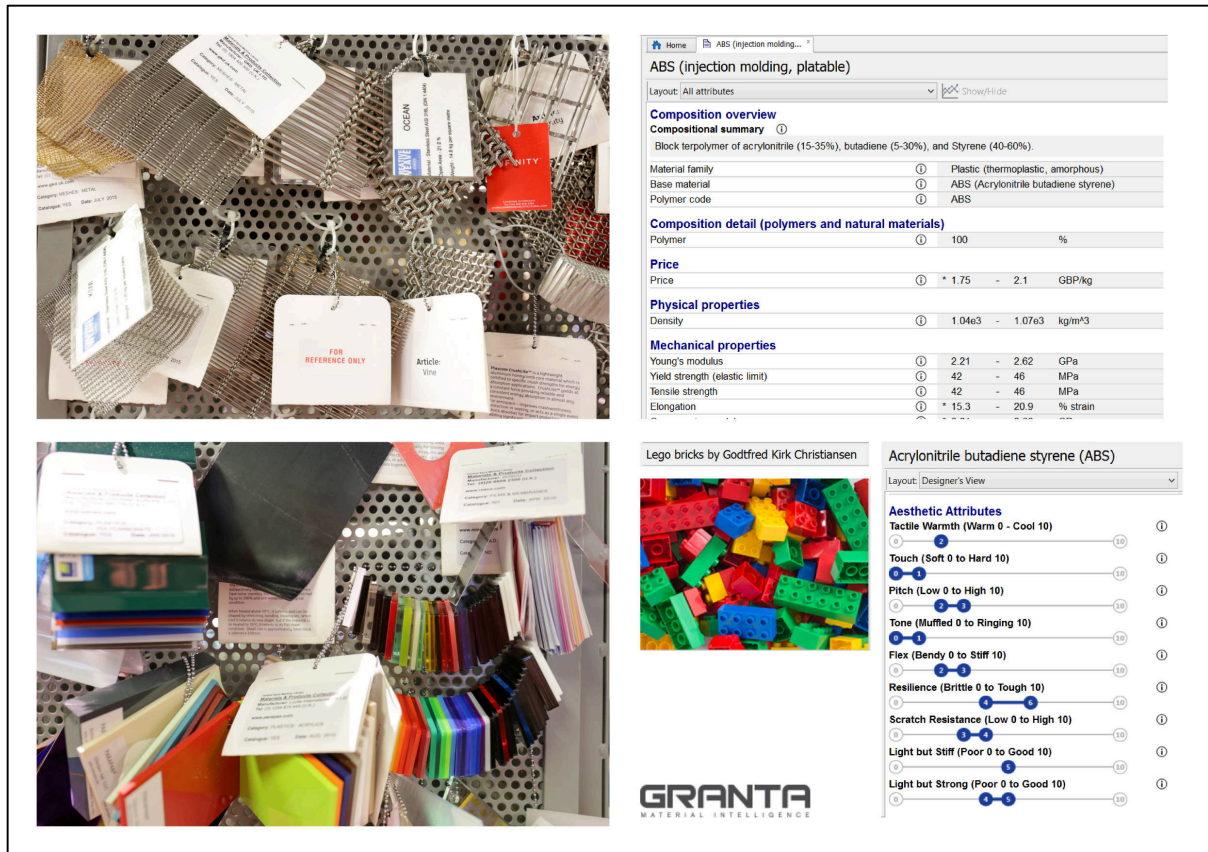


Figure 3. Pristine material samples presented at Central Saint Martins College of Art and Design Materials Collection, London (left); Granta CES Edupack materials database provides detailed engineering material properties (top right), and the new prototype Granta CES ‘Products, Materials and Processes’ database which includes design case studies and aesthetic or experiential material properties (bottom right).

3.2 Simulating material change

To study people’s response to materials that are worn or changed, to create resources to improve designers’ understanding of material change, and to facilitate the development of material surfaces which age in particular ways, it is necessary to *simulate* material change. *Accelerated ageing* is standard practice in many industries from wear testing of prosthetic joints to artificial weathering of construction materials, but there are no test methods for assessing the aesthetic and tactile changes of products in response to normal use, and very limited published work about how people physically interact with products.

In a recent study the authors attempted to develop accelerated ageing methods to simulate both ‘careful use’ (e.g. holding whilst in use and carrying in a pocket) and ‘severe use’ (e.g. carrying in a bag with keys, accidental dropping) of a mobile phone, to enable ‘aged’ material surfaces to be created for user testing, and to test a prototype layered surface finish which was designed to age spectacularly (B Bridgens et al., 2017; B. Bridgens et al., 2015; Lilley et al., 2016) (Figure 4).

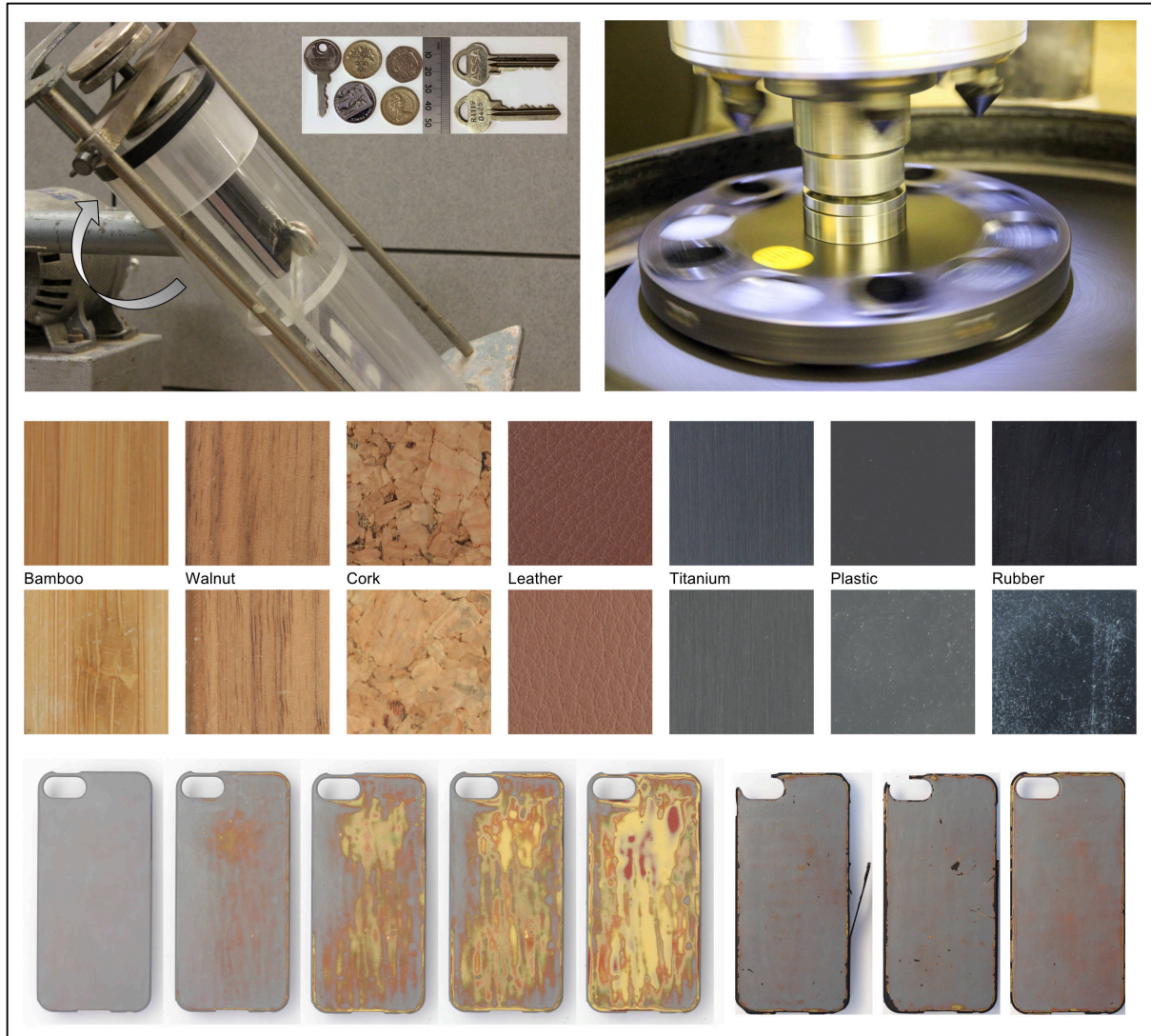


Figure 4. Simulating material change. Development of test methods to simulate ‘wear and tear’ – tumbling with keys and coins to simulate severe wear (top left); polishing to simulate gentle use (top right); a range of materials after repeated cycles of tumbling and polishing used to study people’s reactions to aged materials (centre); layered materials designed to age spectacularly (bottom left), and layered materials after user testing showing unexpected damage (bottom right).

A user study with 36 participants was undertaken to investigate people’s response to the layered surface coating as it changed in use. The layered surface coating was applied to *Apple i-phone 4* cases, which could be placed over participants’ own phones, allowing them to interact as usual with their phone. 12 participants were given cases with no coating (control sample), 12 received coated cases with no pre-explanation of the potential for material change to occur, and 12 were explicitly informed that the coated cases they were given “had the potential to change”. The study was set up to run for 6 months, allowing the effect of context and acclimatisation to gradual change to be studied, as opposed to the visceral response in many materials studies where participants are presented with material samples (Lilley et al., 2016; Wongsrirkusa, Howes, Conreen, & Miodownik, 2012). The intention was to interview participants and photograph the phone cases at 2, 4 and 6 months. However, after 4 months it was clear that the layered surface was not changing as intended, and instead was chipping and flaking, and that damage to the plastic case was also occurring (Figure 4, bottom right).

The damage to the layered phone surface showed that the accelerated ageing test methods do not reflect the actual 'wear and tear' that occurs to a mobile phone in use. There is a clear lack of knowledge of how users interact with their possessions, which will hinder the development of materials that are designed to age or change in particular ways to increase product longevity. Even if people's physical interaction with products was better understood, and suitable accelerated ageing tests could be developed to simulate 'wear and tear', a generic test is unlikely to achieve 'graceful ageing' as the stimuli required are different for each material, and may require a combination of stimuli over varying timescales. For example, ultraviolet light is required to emphasise grain in wood, wax and oil are beneficial to material change of leather and wood, moisture and oxygen are required for patination of copper.

4. Conclusions

A framework has been presented which describes how materials change with use and environmental exposure, and how people might respond to those changes. The framework is intended to provide a tool which can be used to combine information from multiple sources to better understand the interaction of how products are used, how materials change in response to stimuli, and how people will respond to those changes. In each of these areas further work is required to provide sufficient information to enable this tool to be used in the design process.

Improved understanding of material change will enable designers to consider material change throughout the design process. Once material change is considered in tandem with form, use, ergonomics and operating environment, then it may be possible to design for a particular form of material change and extend the emotional durability of products: "patina is a necessary design consideration to assist the extension of product life spans in graceful and socially acceptable ways" (Chapman, 2013, p. 141).

The need for this information is becoming increasingly important as myriad new materials such as fibre reinforced composites, bioplastics and 'DIY materials' (Giuseppe Salvia, 2016; Tanenbaum, Williams, Desjardins, & Tanenbaum, 2013) are developed, for which designers lack any tacit knowledge of how they will change. Accelerated 'wear and tear' testing should enable more rapid, lower risk, adoption of new materials in products.

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