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Could Black Be the New Gold? Design-Driven Challenges in New Sustainable Luxury Materials for Jewelry †

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Abstract: Is there a new material for use in jewelry, matching gold and precious stones, capable of maintaining the same perception of "preciousness" but that is also more sustainable, ethical, and inexpensive? This article deals with a case study within the European EcoDesign Network research project, aimed at investigating how sustainable design can help prestigious companies pinpoint new materials for the creation of jewelry, focusing on new and environmentally friendly opportunities while preserving their market position and target audience. Qualitative and quantitative analyses were performed. Adopting the exploring design path, a jewelry background analysis pointed out both stereotypes and possible innovations in the jewelry field: an analysis was carried out on the perception of jewels by a panel guided by a cognitive ergonomics specialist, also using the eye-tracking machine to examine participants' reactions to the jewelry involved in the study, and to establish paradigms of sustainability, preciousness, and innovation. Several meta-project proposals regarding innovations in materials and finishing were hypothesized and tested, following the main guidelines and principles of ecodesign. Lastly, a prototyping phase and some mechanical tests were implemented to verify the hypotheses of innovation. The results allowed the creation of a first set of sustainable jewelry, currently on the market.

Keywords: materials for sustainability; sustainable luxury eco-innovation; ethical jewelry; goldsmith companies; material experience; materials for behavioral change

1. Introduction

In the early 2010s, we lived in a contingent period characterized by an economic crisis: micro- and small-to-medium enterprises played an important role in boosting economic recovery and a pivotal role in the post-recovery economic landscape. This paper presents a case study of a prestigious Italian goldsmith SME (SMEs are small-and-medium-sized enterprises, defined as having <250 employees and an annual turnover of up to EUR 50 million or a balance sheet total of no more than EUR 43 million) [1] struggling, like many others, due to increasing gold prices in 2011–2013 [2]. According to Hernández Pardo, Bhamra, and Bhamra [3], SMEs often do not possess the knowledge and awareness or capacity for investment to develop sustainable products and processes, even though consumers are becoming increasingly aware of corporate social responsibility, environmental protection, and environmentally friendly products [4].

Let us take a detailed look at the increase in gold prices in the years related to the European EcoDesign Network (EDEN) Cross-Border Network research project (2011–2013), which the company/case study of our article is part of. As shown in Figure 1 and as defined by the Gold Demand Trend 2001 [5], 2011 was a remarkable year for gold worldwide. The price of gold rose by >400% between 2002 and 2012 [6], due to a shift toward safer investments at a time of crisis in the worldwide economy [7]: "since 2001, the price of gold has skyrocketed from a level of US$ 250 per troy ounce to an all-time high of US$ 1900 in August 2011, before falling substantially to around US$ 1200 at the end of June 2013" [8]. In April 2011, *The Guardian* reported, "price of gold—up 27% in the past 12 months and 50% in more than three years" [9].

Figure 1. Mattioli: An overview of products.

1.1. Luxury and Sustainability

Several debates on sustainable consumption of luxury products have been presented in the literature and on the market [10–12]; in fact, not only luxury brands, but also producers of luxury products, particularly high-quality jewelry and clothing, now convey environmental and cultural values to create a relationship with consumers. According to Kim et al. [13], luxury product manufacturers can improve their identity and quality by pursuing sustainable development according to consumers' awareness of social and environmental issues. Numerous authors [11,14,15] have also highlighted the growth of ethical consumption trends and a growing need for transparency of luxury brands: in fact, as underlined by De Pelsmacker et al. in 2005 [16], ethical consumption can help transform consumers' sustainable and conscious attitudes into specific buying behavior.

Ethical consumption [17] covers a wide range of practices and tendencies; it is a term used to cover notions such as human rights, animal welfare, and labor standards and is used against corporate exploitation. However, it can also be considered "ineffective because it is merely used by a minority as a panacea for middle-class guilt" [18], and is a term used by "neoliberal corporations to attract customers and create profit" [18].

The concept of ethical consumption applied to the productive field of jewelry could appear as a contradiction, because of the well-known unethical working conditions of people extracting precious metals and gems in mines [19], the water pollution generated by gold manufacturing, and the bloody conflicts for mineral deposits and territories in Africa [20]. In this context, the key concepts of environmental sustainability and social/moral conscience represent two main goals to be achieved in order to pursue ethical consumption in jewelry [17]. Specifically, with this research, these goals are pursued in terms of lower environmental impact on gold-mining processes with the introduction of new materials that reduce the quantity of gold in jewelry, and a struggle toward global justice by reduced exploitation of miners, with subsequent reduced oppression of "gold slaves", i.e., the people involved in the process of extracting raw materials for jewelry.

Moreover, ethical consumption is also considered from a productive point of view: the jewelry company of the present case study tries to be more sustainable by reducing gold quantity and using a new alloy in combination with a particular finish. The research team paid attention to ethical consumption, considering the environmental impact of the company's production and supply chain and focusing attention on environmental sustainability.

Some research and several articles underline the difficulty and the divergence in terms of values between luxury and sustainable development [4,13] and highlight a weak association between the concepts of sustainability and elegance. However, several scholars, such as Lochard and Murat [21], support the idea that the two concepts are compatible: the sustainability of the project must be presented as a new form of elegance, as an added value to the product, to be universally recognized. Moreover, sustainable luxury is about respect for the social and environmental aspects of production and consumption [11]. Luxury products need not wreak destruction on the environment and the communities that manufacture them [22].

1.2. Consumer Perception of New Material for Sustainability

The consideration of sustainable consumption of luxury products also has to take into account consumer perception of new materials (such as recycled materials, non-precious materials, etc.). As underlined by Achabou and Dekhili [4] in relation to French luxury clothing, "the presence of recycled material in luxury products is perceived negatively by consumers". The issue has been discussed and analyzed in the literature, with particular attention paid to eco-luxury consumer behavior [23]. Being eco-sustainably conscious does not necessarily mean being unfashionable or untrendy [23]; nevertheless, as underlined by De Angelis et al. [15], it is necessary to investigate "how aesthetics affect consumers' perceptions and behavioral intention with regard to new and sustainable products introduced by design-oriented companies (e.g., in luxury fashion)". Looking at the results of De Angelis et al.'s research, "the design of New Green Luxury Products can influence consumers' inclination to embrace them, and ... such an effect importantly depends on both consumer- and product-related factors" [15]. According to the goals of this research, consumers of Mattioli brand products need "to see consistency, in terms of design, between the new green product and the firm's previous models" [15]. For this reason, the paper deals with creating jewelry for the company with a focus on new and environmentally friendly opportunities, always preserving its market position and target audience.

1.3. Gold and Sustainability

It is a well-known fact that gold mining [19], and mining in general [20,24], contributes to global sustainability issues, such as the effects of chemicals like mercury and arsenic on the environment, and ethical issues, such as the exploitation of labor, the financing of dictatorships, and child labor. For these reasons, as reported by *The Guardian* [25], in 2010, two important organizations—Alliance for Responsible Mining and Fairtrade Labelling Organizations International—launched the first Fair Trade certification for gold, in order to boost certified gold miners. Moreover, "in 2012, the World Gold

Council set up its Conflict-Free Gold Standard, which enables gold producers to provide assurance that their operations do not support unlawful armed conflict" [25].

Consumers demand responsibly sourced gold that goes by different names, taking into account its mining and recovery processes and recycling chains, e.g., eco-friendly, ethical, and recycled gold. These types of gold are already used in jewelry production, in forms such as lightened gold (375/1000 or 9 K gold, for example), in which the percentage of pure gold is reduced (33%) compared to 18 K (75% pure gold) or 12 K (50% pure gold). The latter two gold alloys are more popular in Italy, thanks to their golden color, and are more appreciated by consumers of luxury jewelry. For this reason, this paper aims to explore how designing for sustainability can support companies, and particularly SMEs, in developing new solutions for selecting innovative materials and processes for jewelry that are mixed with gold or completely replace it.

After this Introduction to the work context, Section 2 will look at the materials and methods used to explore how black can be the new gold and explain how to develop new proposals for sustainable gold jewelry. In Section 3, the test results are presented, and in Section 4, the relationship between the outcomes of the study and its relevance for the scientific community as well as jewelry producers, managers, and designers are discussed, along with the limitations of the study and the direction in which future research is heading. Lastly, Section 5 presents the main conclusion of this research.

2. Materials and Methods

2.1. The European Reasearch Context

This paper deals with research dedicated to one of the case studies selected within the EDEN research project (for more details, see [26]), aimed at engineering eco-compatible products, included in the Interreg-Alcotra Program 2007–2013 to support the creation of innovative, environmentally sustainable products and processes by SMEs in Piedmont. By working with SMEs and adopting ecodesign strategies such as material substitution, application in new fields, and conversion of some manufacturing activities to green processes, it is possible to demonstrate how design strategies can be improved not only in their individual environmental performance, but also in the way they enhance a company's brand identity.

2.2. The Case Study: Mattioli

As indicated above, the research presented in this paper is focused on a specific case study of Mattioli, an Italian goldsmith that produces jewelry for its product lines and several other famed international brands (Figure 1). The Mattioli brand has a noble past, associated with the most famous and masterful goldsmithing tradition of Turin; Mattioli's history is rooted in the Antica Ditta Marchisio, established in Turin in 1860. Mattioli launched its own brand in 2000, showcasing jewelry that stands out for its contemporary and soft shapes, as well as the balance between artisan quality and innovation in materials and technologies [2]. Mattioli is always looking for new technologies and new processes and merging different sectors, taking into account environmental sustainability; the challenge is to introduce eco-sustainability into jewelry, sourcing and testing materials to be paired with gold [27].

2.3. Methods

The research focusing on the case study previously presented has been organized into four main steps, each using specific methodologies currently adopted in the design process:

- Adopting the exploring design path [28], thanks to a customized scenario investigation of the jewelry world, both the commonalities shared by every jewelry item and possible new options representing innovations in the field have been highlighted. This overview focuses on materials, processes, sustainability, relationships with manufacturers, and new parts that could complete or coordinate with jewelry. In this phase, various aspects of the jewelry sector have been analyzed, such as materials to substitute for or pair with gold; different technologies and jewel-making typologies; new elements that could integrate with or accompany jewelry in general. All these

aspects have been studied, with attention given to the sustainable aspects of jewelry-making processes and production and to the value of the perception of sustainability, as well as connections between the precious product and its territory, in relation to materials, finishes, and languages.

- An analysis of the perception of jewels was carried out in research sessions with a panel guided by a cognitive ergonomics specialist, using the eye-tracking machine to examine participants' reactions to the jewelry created by the company under study, in order to establish paradigms of preciousness, innovation, and sustainability.
- The technological crossbreed method [29] helped manufacturing companies to identify materials, semifinished products, and components from different productive fields that can be used in unconventional interpretations for innovative products. Using technological crossbreeding, firms can explore new products and new potential, benefitting from previous tests and experiences in the specific contexts in which materials, semifinished products, and components are generally used.
- Lastly, comparative analysis and laboratory tests were performed to verify the effectiveness of the proposed solutions in terms of new materials and finishes for sustainable jewelry.

2.3.1. The Exploring Design Path

Following recent design culture studies, the exploring design process is a response to the economic crisis recently affecting Western countries, generating new working methods [30] to cope with the weakened role of traditional customers and define products and services for the future [31]. In recent years at Politecnico di Torino, research in education has been devoted to evolving a new methodological model [28]. The exploring design path was developed based on Giuseppe Ciribini's requirement theory [32] and Christopher Alexander's lessons [33] to define a methodological approach that can be used for any designing action, based on a rigorous matching of project requirements and performance. The method is organized in three fundamental levels:

- Concept design, in response to the question: "How to do?" (focused on the performance system definition, beginning from fixed typologies and functions);
- Scenario design, in response to the question: "What to do?" (focused on the scenario analysis, beginning from fixed materials and technologies); and
- Exploring design, in response to the question: "Where to do?" (focused on the metadesign phase, beginning from a spread ambit to investigate).

The design path is articulated in two macro-phases, corresponding to different points in the project: metadesign and design. The metadesign phase is composed of scenario analysis and performance system definition. With this method, the metadesign phase has more value and the scenario analysis becomes central. This method is relevant for our study because it enables the designer to seek new environments for research, expanding the horizon of innovation in a divergent and then convergent thinking process, according to design thinking methodology [34]. By following this model, a complete scenario analysis, i.e., a state of the art, is developed to understand the current production of the company under study and to define possible development lines. The work team sketched a background analysis that considered the most important information, like the history of the enterprise, technologies in use, the production chain, and marketing strategies, to rate the firm's level of innovation and its sustainable behavior. Specifically, both the company's current production and the products of its competitors were analyzed, focusing on production processes, materials, environmental sustainability, and innovation, according to the ecodesign guidelines [35–37].

2.3.2. Analysis of the Perception of Jewelry

The perception of jewelry was analyzed in three phases. The first phase was aimed at identifying the "weak signals" that can be hidden behind the "precious jewel" concept, to better understand the value and role of gold in contemporary jewelry. A group of eight participants (women, mean age = 43.0 years, standard deviation = 3.5 years) was selected from a wider group, because they matched

the description of a "Mattioli woman customer" (30–50 years of age, financially independent, positive attitude toward buying jewelry), and they voluntarily participated in the study. Each participant completed a quali-quantitative questionnaire on her behavior when buying jewelry and on her knowledge of the Mattioli brand. The questionnaire required answers to some fundamental questions necessary to direct the research, pointing out the preferred precious and non-precious materials in jewelry.

A creative phase based on cognitive maps [38] of "preciousness" and "jewel" concepts, free associations [39], and collage techniques [40] was undertaken with the same panel, guided by a cognitive ergonomics specialist. This activity particularly helped with further investigation of the different precious/non-precious materials previously identified, possible material combinations and pairings, and possible coatings, finishes, and colors (Figure 2).

In the next phase, the same participants used another common tool in qualitative research [41], an eye-tracking machine (which records a person's eye movements while looking at an object or browsing a website), to look at Mattioli jewelry while listening to specific words as stimuli, such as "sustainability" or "innovation". This activity allowed an objective understanding of which elements (materials, colors, shapes, finishes) evoked aspects such as "luxury", "innovation", and "sustainability".

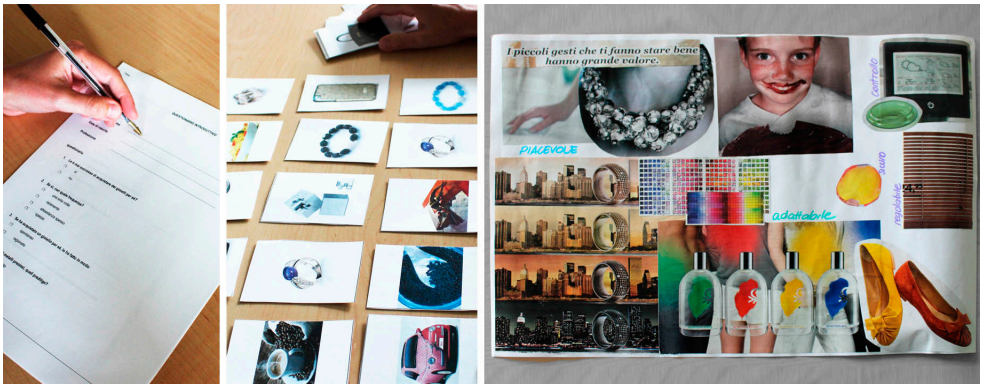

Figure 2. Some moments of the creative phase: questionnaire (on the left), free association (in the middle), and collage (on the right).

2.3.3. The Technological Crossbreed Investigation

Several proposals for meta-projects (i.e., meta-design indications without specific solutions that will be implemented) regarding innovation in materials and finishing have been hypothesized, following the guidelines and principles of ecodesign (for a complete review of ecodesign methods and tools, see [42]). According to Karana et al. [43], materials and finishes were selected in order to satisfy functional requirements for specific needs, e.g., for their expressive characteristics, to intrigue the senses, or for their reduced environmental impact compared to traditional gold. Surface finishing appeared to be the most interesting solution, due to its ability to change the materials' visual characteristics while retaining their technical properties. Specifically, black was defined as the most suitable color for this challenge, due to its association with the concepts of preciousness and elegance [44,45], as well as its ability to preserve the company's identity and elegance; in fact, never more than in this case has the crucial role of intangible characteristics of materials [46] been so evident.

Diamond-like-carbon (DLC) coating finish was hypothesized as a possible solution for reproducing black gold, with both matte and glossy effects [47]. It results from plasma-assisted chemical vapor deposition and is available as an advanced surface finish, characterized by its high technical properties, quite similar to physical vapor deposition coating, but better performing [48]. Thanks to its outstanding technical characteristics, DLC is currently used for watches, pens, cutlery, and shaping tools, as well as in the automotive, aerospace, and military industries and the health care sector, as it ensures biocompatibility [49] and resistance to wear and corrosion of the substrate on which it is deposited.

The transfer of technology from these sectors, which are continually seeking innovation in materials and technologies, to jewelry offers new opportunities to enhance both project value and innovation, maintaining the well-known preciousness of gold.

Then, in accordance with environmental (e.g., lower impact on resource consumption), functional (e.g., resistance to wear and chemicals, hardness, great adhesion to substrate material), and communication (e.g., the possibility to color the surface with black finishing) needs of the new jewelry, non-precious materials such as stainless steel, aluminum alloys, and copper-beryllium alloys were considered to accompany gold and the DLC coating to turn "cheap" materials into precious ones using a black-colored finish.

2.3.4. Comparative Analysis and Laboratory Tests

An investigation was carried out of the environmental impact of alternative materials considered for jewelry (as well as gold), based on embodied energy, CO_2 footprint, and water usage indicators [50] in the two steps of primary production and recycling of the materials, using the CES Selector (2013 version; Granta Design Ltd., Cambridge, UK).

To prepare the samples, the research team proceeded as follows. The Yin Yang ring by Mattioli was selected as a sample shape for the laboratory tests, due to the complementarity of the two items making up the ring and the consequent rubbing between the two parts of the ring. Six (3×2) samples of the ring, without stones or mounted elements, were produced ad hoc using the lost-wax micro-casting technique by Mattioli (two in stainless steel, two in aluminum alloy, and two in copper-beryllium alloy), then degreased, washed, dry-polished, and DLC coated by a supplier firm. Each pair of samples was produced with a glossy and a matte surface. The samples were subjected to a preliminary visual test performed with an optical metallographic microscope (Leica MEF4M) at 20× magnification, in order to verify the standard coating quality before the wear resistance test. All the samples underwent the same mechanical wear resistance test, i.e., the "handbag" test, a sort of tumbling machine simulating the common wear conditions of jewelry over time [51], derived from testing protocols in the literature [52]. The test was performed in the Politecnico di Torino labs with a 3D-motion Turbula mixer, a tumbling machine with planetary three-dimensional motion, equipped with corundum powder (granulometry < 20 μm, equivalent to 20%). The samples were observed at intervals of 1, 2, 3, 5, 10, 15, and 25 min, and compared after each interval with a stereo microscope (Leica MS5) at 6.3× magnification.

3. Results

The methods used—the exploring design path and the technological crossbreed—as well as the analysis of the perception of the jewelry, the comparison between materials in terms of environmental impact, and the laboratory tests all allowed a focus on the following key aspects and results in this research context.

3.1. Environmental Impact Analysis and Mechanical Test Results

The preliminary analysis of the environmental impact of the alternative materials for jewelry showed that, overall, all three materials (stainless steel, aluminum alloy, and copper–beryllium alloy) had far lower environmental impact than gold, taken as the reference material. Consequently, each of these materials could be a profitable choice to reduce the environmental impact of today's gold jewelry (Table 1 shows every measure as a value range). Apart from the comparison between the alternative materials and gold, stainless steel appears to have the lowest impact of the three. Aluminum alloy and copper–beryllium alloy, on the other hand, can be considered as alternatives on the basis of this investigation.

Table 1. Comparison between different materials to be paired with gold with regard to environmental impact.

		Compared Materials			Reference *
Evaluation Criterion		**Stainless Steel**	**Aluminum Alloy**	**Copper–Beryllium Alloy**	**Gold (High Alloy)**
Embodied energy (MJ/kg)	P	95.7–106	191–211	150–165	231,000–255,000
	R	19.2–21.3	23.9–26.4	27–29.9	7160–7910
CO_2 footprint (kg/kg)	P	5.95–6.58	11.5–12.7	9.47–10.5	13,500–14,900
	R	1.51–1.67	1.88–2.08	2.12–2.35	563–622
Water usage (L/kg)	P	144–159	1050–1160	294–325	249,000–27,5000

Note: P = primary production; R = recycling; * gold (high alloy) was used as a reference for the impact of the currently adopted material.

In the next step of the study, stainless steel, aluminum alloy, and copper–beryllium alloy samples were coated with DLC. As a first result, the thin DLC coating film did not mask the starting surface macro-imperfections. Furthermore, the DLC coating surface on the copper–beryllium alloy sample appeared more uneven, patchy, and yellowish, i.e., leading to yellow color, than on the other samples. On the other hand, the coating presented a darker and more even black color on the stainless steel and aluminum alloy samples.

In the visual analysis performed after the mechanical test, the DLC–aluminum alloy sample showed widespread abrasion on the entire surface after 1 min of the test, the DLC–copper–beryllium alloy sample showed an even matte effect after 15 min, and the DLC–stainless steel sample showed an even matte effect after 5 min.

Globally, the DLC coating on the stainless steel sample proved to be a more effective solution in terms of both visual characteristics of the finish—i.e., a dark and even black color—and mechanical resistance to the test.

3.2. "Symbolic" and "Accessory" Jewelry

The analysis of jewelry perception, with cognitive sessions supported by the eye-tracking machine, produced four distinct aspects of jewelry, which seem to be four possible ways to read and perceive jewelry: "elegance", which seems to focus on added elements, such as diamonds and other precious stones; "preciousness", which emerged as a category that is sought for both shape and added precious elements (both of these show sensitivity to particular colors); and the "symbolic" and "accessory" aspects, which emerged as categories that are freer from stereotypes, open to material innovation and new shapes, and associated with customization. Accessory jewelry suggests the concept of originality that should highlight precious elements, without avoiding non-precious components. Moreover, for symbolic jewelry and accessory jewelry, uniqueness seems to be a key element, considered from a materials perspective—i.e., innovative material—or from an aesthetic perspective—i.e., new shape.

According to the concepts of symbolic and accessory jewelry, the research team proposed innovative solutions for material and finishing where gold is the precious element, highlighted by a non-precious black frame (Figure 3). According to the results of this study, the material selected as a frame for the precious gold part of the jewelry is steel, which is better in terms of resistance to wear and from a visual perspective.

The elegance and preciousness of jewelry are guaranteed, because gold has been transformed into the precious added element (instead of diamonds or other precious stones) of the jewelry; the color black is associated with elegance [45], and is also seen as technologically and aesthetically innovative.

The research team indicated several solutions whereby gold can coexist with another material according to the analysis and the data on the environmental impact of alternative materials. As a result, the elegance and preciousness of the jewelry are assured and, at the same time, the jewelry is characterized by a material and environmental lightness, which is obtained by reducing the quantity of gold used in favor of steel elements with an elegant black finish.

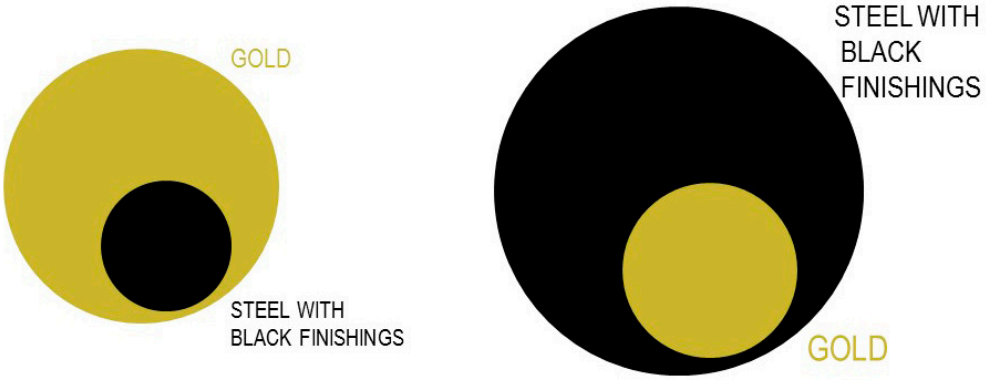

Figure 3. Meta-design proposal: how can gold and other metals coexist? On the left, the additional element apparently enhances the black jewelry, reducing the amount of gold present. On the right, the big black component significantly reduces the amount of gold, enhancing its presence.

4. Discussion

This research shows how businesses, even in sectors traditionally linked to critical materials, are responding to several challenges, such as integrating cultural issues, communities, environmental behavior, economy, and sustainable technology, by introducing innovative materials into their production processes through design research [53]. The positive findings of this study in terms of materials and design opportunities, sustainable implications, marketing, and management will be discussed in the following paragraphs.

4.1. Design and Sustainable Implications, Future Research Directions

From an industrial design perspective, it seems important to underline that the "core" of the activity described in the present study is represented not by a new shape or a new product conception, but by the conscious choice of a black surface treatment for new non-precious metal alloys, and its transfer from another commodity-related field as the winning design strategy to enhance the jewelry company's ethical production [14]. In other words, the new alloy combined with a particular black finish (the result of this study) could impact responsible consumer choice based on individual self-fulfillment. The choice will imply having perhaps less precious jewelry, but jewelry more respectful of human rights and the environment. The new jewelry will encourage an intellectual attitude of voluntary downshifting, due to a renewed sense of caring about others and nature [54]. This is a bottom-up path, from coatings and processes to new products that are not simply more affordable versions of pieces of luxury jewelry.

From the sustainability perspective, in a world with challenges involving concerns such as sustainability in production, ethical life cycle, and conscious resource consumption, this study presents an approach that enhances the value of technology transfer to sectors, materials, and products that are traditionally very distant from each other [55]. The cross-fertilization derived from multidisciplinary, interdisciplinary, and transdisciplinary approaches to design research has proven once again that it is a key driver in stimulating innovative production processes [56]. In fact, after this research, Mattioli adopted stainless steel with DLC coating for one of its product lines, the Yin Yang collection (Figure 4). The decision to use stainless steel–DLC was based on the better results obtained in terms of mechanical resistance and visual quality. The better results from the mechanical tests, in fact, were obtained with the samples produced with a harder substrate. This evidence allows us to assume that the overall resistance of the coating is highly correlated with the substrate hardness [48], but several other tests using other material samples should be performed to prove it.

Figure 4. The Yin Yang collection, for which Mattioli adopted stainless steel with DLC coating (currently on the market).

The use of materials other than stainless steel finished with DLC coating is currently under investigation. For example, in the future, light alloys usually used in aeronautics and aerospace—e.g., titanium and aluminum alloys—could be explored and tested. This could allow the hypothesizing of a virtuous circular supply chain in which materials could even come from other production chain waste. This opportunity could strengthen Mattioli's expansion into the Piedmont region, which is home to some of the most important Italian aerospace enterprises. In this case, too, the black coating could legitimize the new material in the field of golden and sparkling surfaces, maintaining high cultural and social value of the jewelry [57]. Furthermore, light alloys could be transformed through innovative technologies, such as rapid prototyping. In short, such alloys lend themselves to conveying the spirit that Mattioli stands for, as well as interpreting today's paradigms of complexity and fluidity and the resulting stylistic elements (the "impossible shapes") through processing technologies that enable production flexibility and cost control. The consequences of the company's improved attitude toward sustainability, as well as customers' more ethical approach to jewelry appear to be clear within a similar action of creating a "new gold" capable of playing an important role in the transition to a more sustainable planet.

4.2. From Case Study to Best Practice: Marketing and Management Implications

From a marketing and management perspective, the concepts of responsible luxury [58] and sustainable luxury [12] represent a complex challenge. Through the ecodesign activities presented in this study, a jewelry company is able to tackle its market quota loss and, moreover, confirm its central role in the Italian jewelry market by strengthening its identity as a sustainable and innovative company dedicated to a specific target, educated women capable of appreciating the luxury and elegance, not only the preciousness, of the product [59]. However, international tastes and preferences are very different: something like the black finish could be successful in some countries and misunderstood in others. This can be considered as a limitation of the present study, as well as a key driver for future investigations. The consideration that arises from this experience is that it could be useful for the jewelry design team to consider cultural differences in public preference, e.g., with specific in-depth studies, starting from the very first phases of jewelry design [60]. Lastly, the company's sales staff and buyers have to be trained in evolved communication in order to understand the "sense" of the operation and the product, to better communicate its innovative value to future customers.

From a social and behavioral perspective, the new black gold could be considered as an innovation toward more sustainable products and processes for the entire jewelry industry, starting from technical finishing that finds a new application in an innovative production field. This innovation, developed and launched by one of the most important Italian goldsmiths, if taken up as a national best practice for corporate social responsibility, could represent a resonant driver of behavioral change by manufacturers and consumers toward the topic of "non-gold" jewelry in the years to come. In fact, the introduction

of an innovative, ethical, and less environmentally impactive material into jewelry could represent a key point in the purchase of luxury products by consumers [61], as well as a step forward in a field traditionally linked to luxury, and to the resulting exploitation of people and resources.

Lastly, the practice presented in this study shows how to support and encourage the sustainable growth of SMEs: research and universities support an enterprise by creating a model for the development of sustainable products and processes on a local and global scale. Even if this best practice is focused within a local context (Piedmont), it could become an important reference for national and international institutions and companies and be replicated in other territorial contexts, thanks to the scalability and repeatability of the adopted methods of ecodesign.

5. Conclusions

This research project highlights the efficacy of sustainable design in helping SMEs to define new materials and technologies (e.g., surface finishing) to boost the design of new green luxury products [28]. As introduced by this study, companies can take advantage of the use of specific methodologies currently adopted in the design process. Specifically, the Mattioli company could benefit from new strategies for replacing gold with alternative ethical and sustainable non-precious materials. This allows a reduction in the amount of gold used in jewelry, which addresses the problem of the soaring price of gold in recent years. Nevertheless, the strategies identified were selected for their coherence with the elegance and preciousness that are associated with Mattioli jewelry and characterize the Mattioli brand. These elements show that design and ecodesign represent key drivers for more sustainable production, even in traditional and luxury sectors such as jewelry; Mattioli is a best-practice example in this context of development toward ethics and sustainability in jewelry.

We can conclude that there is now a new material for use in jewelry that, paired with gold and precious stones, is able to maintain the perception of "preciousness" while being more sustainable, ethical, and inexpensive.

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