APPENDICES

A PROJECT BRIEF

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Aarts 4485
initials: R.M.A. given name: Resy
student number: 4450191
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): ★ IPD / DfI / SPD
2nd non-IDE master: n/a
individual programme: - - (give date of approval)
honours programme: Honours Programme Master
specialisation / annotation: Medisign / Tech. in Sustainable Design / Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Jansen, K.M.B. dept. / section: Emerging Materials
** mentor: Slingerland, M. dept. / section: Technical Support
2nd mentor: n/a
organisation: n/a
city: n/a country: n/a
comments (optional): n/a

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

TU Delft

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair: Jansen, K.M.B. date: 08 - 10 - 2020 signature: Kaspar Jansen (Digitally signed by Kaspar Jansen Date: 2020.10.08 10:28:10 +02'00')

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 39 EC
Of which, taking the conditional requirements into account, can be part of the exam programme: 30 EC
List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed
NO missing 1st year master courses are:

name: C. van der Bunt date: 09 - 10 - 2020 signature:

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ★ APPROVED / NOT APPROVED
Procedure: ★ APPROVED / NOT APPROVED

remark: the title should be defined more clearly: (with the words exploration, design guide and demo)
comments

name: Monique von Morgen date: 27 - 10 - 2020 signature:

Initials & Name: R.M.A. Aarts 4485 Student number: 4450191
Title of Project: Electrochromic materials for use within product design

Personal Project Brief - IDE Master Graduation

TU Delft

Electrochromic materials for use within product design — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date: 06 - 10 - 2020 end date: 23 - 04 - 2021

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Within this project the possibilities of electrochromic materials within product design will be explored. They can be of great interest in product design due to their color changing abilities, memory effect and low voltage operations. Although there are some applications of this material in product design; smart windows and antiglare devices, lots of potential for product design still needs to be explored. For this reason, I would state "product designers" as main stakeholders in this project. Also the "emerging material department" of the TU Delft is a main stakeholder, since next to possibilities of design with the material itself, also possibilities of prototyping (in the Applied Labs) will be researched.

Note that "product designers" feels like a broad stakeholder, this is since no intended use of the material will be specified at the start of the project. The material will be researched and later in the project possible applications will be defined.

Smart windows, antiglare devices and batteries are in general the main product classes that can be found that implemented an electrochromic material. In literature, prototypes and demonstrators can be found, but no implementations. This combined with little knowledge, I believe that product designers not really use/consider this material in their design, as it is easier to take a material/device they know than to research a material they have little/no knowledge about.

The main opportunities of this material are the color changing and memory effect ability, its low operation value and non-light emittance. Rapid prototyping seems to be easy done, however this is still to be researched.
The main limitations/challenges will be the slow operation times of the material, resolution challenges and protype electrochromic devices that contain liquids.

space available for images / figures on next page

Initials & Name: R.M.A. Aarts 4485 Student number: 4450191
Title of Project: Electrochromic materials for use within product design

Personal Project Brief - IDE Master Graduation

introduction (continued): space for images

image / figure 1: Ynvisible electrochromic display. Copyright by Ynvisible.

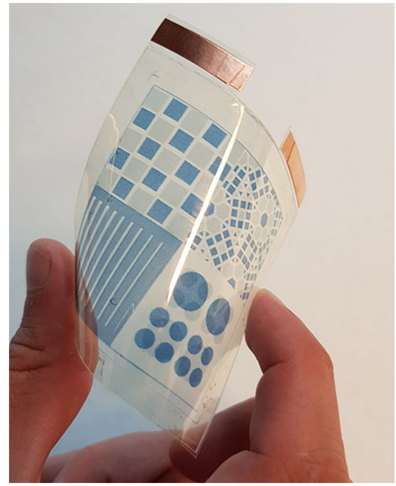


image / figure 2: TransPrint electrochromic display. Copyright by Jensen (2019).

Personal Project Brief - IDE Master Graduation

PROBLEM DEFINITION **
Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Electrochromic materials are smart materials that change color when electricity is applied to it. These materials exhibit the memory effect, meaning no current is needed after the color change took place; the device stays in its new color state until the reverse current is applied to it, then it changes back to its original colored state. This results in low voltage operation.

All these aspects can be of great interest in product design. Which is also the goal of this project: to implement electrochromic materials in product design.

First, the material aspects of different kinds of electrochromic material will be briefly studied, with their applications and prototyping possibilities. With this knowledge, (simple) working protypes of electrochromic devices will be made in the Applied Labs at the faculty. This hands-on experience will be translated into possibilities for product design. Due to combining the prototyping experience with the knowledge gathered, different product design areas will be explored. What opportunities does this material offer for product design? From this exploration, one design will be further developed and designed into a realistic product concept. Ideally, a working prototype of this concept design will be created.

ASSIGNMENT **
State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

The characteristics and possibilities of electrochromic materials and electrochromic devices will be explored through research and prototyping. This exploration will then be translated into product design opportunities, which will lead to a realistic product design concept implementing electrochromic materials.

In the end, a brief explanation of electrochromic materials will be provided with a guide for designers. The aim of this project is to both create an example of material driven design with electrochromic materials, but also to simplify this process for other product designers in the future.

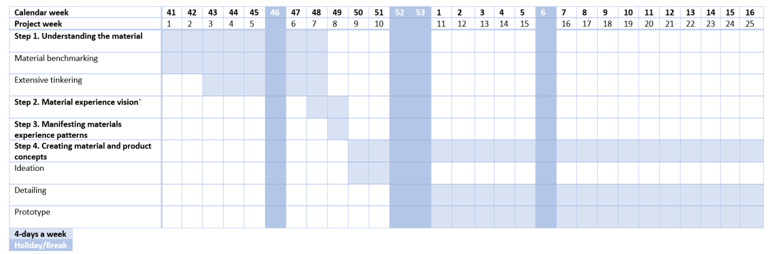
First of all, the example of material driven design with electrochromic materials will include a realistic concept design, detailed developed by means of visuals, a demonstrator of the electrochromism and ideally also a working prototype.

Secondly, the guide for designers will include a brief overview of electrochromism and electrochromic materials with a roadmap on how to use these in product design.

Personal Project Brief - IDE Master Graduation

PLANNING AND APPROACH **
Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 6 - 10 - 2020 23 - 4 - 2021 end date



Note that the total of 25 weeks is due to the fact that 4 days in a week will be taken to graduate (instead of 5 days); part-time. The 5th day in the week, I'll spend on working for my job at the TU Delft Gamelab (8 hours a week).

Within the planning, 4 weeks of holiday are included. The first in the week of the 9th of November, the second and third are the Christmas holidays (21th of December- 1st of January) and the fourth week is the week of the 8th of February.

Material Driven Design method will be used:
Step 1: Understanding the material
- Material benchmarking through literature research.
- Extensive tinkering to determine the technical and experimental characterization of the material.
Step 2: Creating materials experience vision
- Reflect upon unique qualities of the material and translate them into product offerings (areas of applications).
- What role the material might play in relation to a product, its user and the context.
Step 3: Manifesting materials experience patterns
- Explore experimental qualities of the material further.
Step 4: Creating material or product concepts
- Ideation of the material within products in different areas of applications.
- Detailing of one of the ideas into a realistic product concept.
- Prototype this product concept. (Note that detailing and prototyping will be an iterative process).

Personal Project Brief - IDE Master Graduation

MOTIVATION AND PERSONAL AMBITIONS
Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

First of all, the material I'm going to work with in my graduation is a smart material. The reason I choose to do a project with a smart material is due my personal interest in materials. It is fascinating to see what a designer can accomplish when have chosen the right material for its application. As mentioned before, electrochromic materials are materials that change their color due to an applied potential. I feel that this specific material can offer lots of possibilities within product design in general.
Another interesting aspect of this project is that due to the material driven design aspect, I have no idea what kind of product (concept) I'm going to design in the end. Exploring this material with no intended use in mind, will keep a lot of design options open, which later on can be further defined within the project.
Finally, the best aspect about this project that it is material driven design instead of problem driven design. I feel that I have experienced a lot of problem/opportunity design driven design within my studies, but never started with a specific material. This, makes it even more interesting for me.

Personal learning ambitions:
1. Learn more about the material driven design method;
2. Broaden my knowledge on the possibilities of designing with (smart) materials; electrochromism.
3. Learn how to prototype with electrochromic materials.

To explain my personal learning ambition 2: within this project one smart material phenomenon (electrochromic materials) is chosen. To execute this (material driven design) project with this specific smart material, I believe I'll develop knowledge on how to implement possible other materials in the future. This will of course, largely differ per material, but at least I'll have more knowledge about the possibilities of designing with smart materials.

FINAL COMMENTS
In case your project brief needs final comments, please add any information you think is relevant.

B MATERIAL DRIVEN DESIGN METHOD

The material driven design method facilitates design for material experiences. (Boeijen, Daalhuizen, & Zijlstra, 2020). It explores what the material is, does, expresses to us, elicits from and makes to us. According to Karana et al., (2015), the Material Driven Design method reflects an understanding that a material with its properties, potential applications, and performance affects users and gives rise to unique user experiences.

The Material Driven Design method consists of four steps: (Boeijen et al., 2020; Karana, Barati, Rognoli, & Zeeuw van der Laan, 2015)

Step 1: Understanding the material
- Material benchmarking (position the material within a group of similar materials and their applications);
- Extensive tinkering to determine the technical and experimental characterizations of the material;
  - "How the material at hand is appraised by intended users"; (Karana et al., 2015)
  - "How the material is experienced on sensorial, interpretative, affective and performative levels" (Karana et al., 2015)
  - "How these experiences relate to physical (engineering) properties of the material" (Karana et al., 2015)
- According to Karana et al. (2015), the final goal of the first step is to understand the engineering limitations and unique technical properties of the material.

Step 2: Creating materials experience vision
- Reflect upon unique qualities of the material and translate them into product offerings (areas of applications);
- Define the (possible) roles of the material in relation to product, user and context.

Step 3: Manifesting materials experience patterns
- Explore experimental qualities of the material further.

Step 4: Creating material or product concepts
- Ideation of products using the material in different areas of application;
- Detailing of one of these ideas into a realistic product concept design;
- Prototyping of this product concept. (Note that within this project detailing and prototyping will be an iterative process).

"In the MDD Method, we particularly emphasize that a selected concept should be prototyped with the final material choice and tested not only under controlled conditions (e.g. mechanical test, user perception tests, etc.) but also in the field (e.g. putting the concept within its actual context, observing peoples' reactions, interviewing and users, etc.). (Karana et al., 2015)

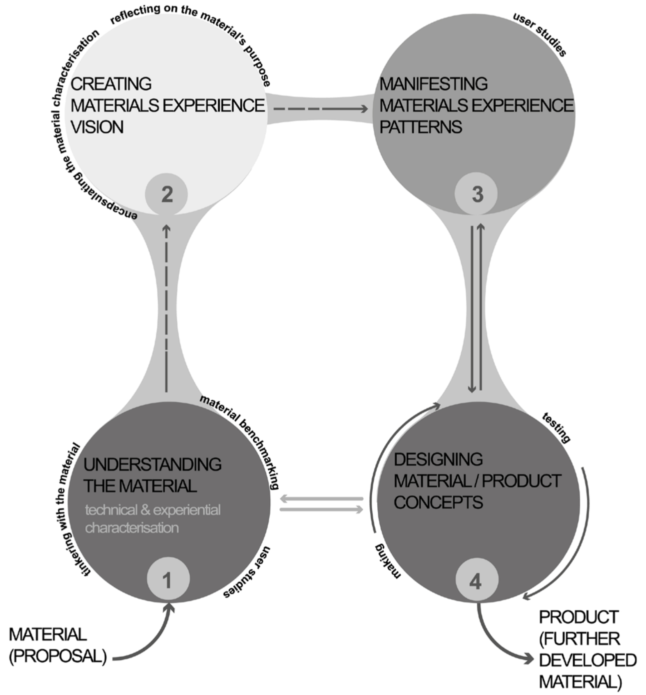


Figure B.1: The Material Driven Design method. Copyright by Karana et al., (2015).

This page is intentionally left blank

C QR-CODES AND URL

QR-code 1: SageGlass:
Glass that tints on demand

URL: https://www.youtube.com/watch?v=pgFoI6gvGSk&ab_channel=SageGlass

QR-code 2: Switching between the bleached and colored state.

URL: https://www.youtube.com/watch?v=JDnnkzQMl0Y&ab_channel=ResyAarts

QR-code 3: Coloring of an ECD.

URL: https://www.youtube.com/watch?v=_jjx0WRjh2Y&ab_channel=ResyAarts

QR-code 4: The four stacking sequences of an ECD.

URL: https://www.youtube.com/watch?v=8BtvHBQmTiA&ab_channel=ResyAarts

QR-code 5: ECD-C-89: eight image display.

URL: https://www.youtube.com/watch?v=PlnD89WpO_Q&ab_channel=ResyAarts

QR-code 6: Color flow within co-planar displays.

URL: https://www.youtube.com/watch?v=IX8Ei0HCgF8&ab_channel=ResyAarts

QR-code 7: Vertical SS#2: immediate coloring and color flow combined.

URL: https://www.youtube.com/watch?v=0iRqtWK83mc&ab_channel=ResyAarts

QR-code 8: Different colors: color change.

URL: https://www.youtube.com/watch?v=tvqnV2UgXX0&ab_channel=ResyAarts

QR-code 9: Proof of concept.

URL: https://www.youtube.com/watch?v=KeUvF5xLqTE&feature=youtu.be&ab_channel=ResyAarts

QR-code 10: 'The puzzle of electrochromism': demonstrating the opportunties of EC materials in product design.

URL: https://www.youtube.com/watch?v=LvrPQAJKRVo&ab_channel=ResyAarts

QR-code 11: Individual puzzle pieces.

URL: https://www.youtube.com/watch?v=MiMRjhjVY1Q&ab_channel=ResyAarts

D CURRENT APPLICATIONS

As mentioned in the introduction, although electrochromic materials are already implemented in applications that are on the market, there is still lots of potential within the field of product design.

Electrochromic materials are primarily implemented into glass; i.e. smart glass or smart windows. Besides this, a couple of applications within the automotive industry are known; i.e. self-darkening windows or anti-glare mirrors. And a couple of companies offer rapid prototypes using electrochromic materials.

D.1. SMART GLASS

Companies such as SAGE Electrochromics, Gentex Corporation and ChromoGenics are specialized in integrating electrochromic materials within glass; i.e. ***electrochromic glass***, smart glass or dynamic glass. However, as their product portfolio indicates, no further explorations of different product categories are explored by these companies.

SageGlass is an electronically tintable glass that is used for windows, skylights, facades and curtain walls (SageGlass, 2018). According to their product portfolio, the SageGlass is at least implemented into 82 buildings, varying from office buildings to cultural institutions, airports and healthcare facilities. For example, as can be seen in figure D.1, it is implemented in the rooftop window of the government center Utrecht. According to SageGlass (2018), SageGlass improves comfort, and maximizes daylight and outdoor views while reducing the energy costs. As can be seen in figure D.2, the electrochromic layer ("SageGlass coating) is implemented at the inside of the outer glass of the window.

Figure D.1: SageGlass: Government center Utrecht. Copyright by SageGlass (2018)

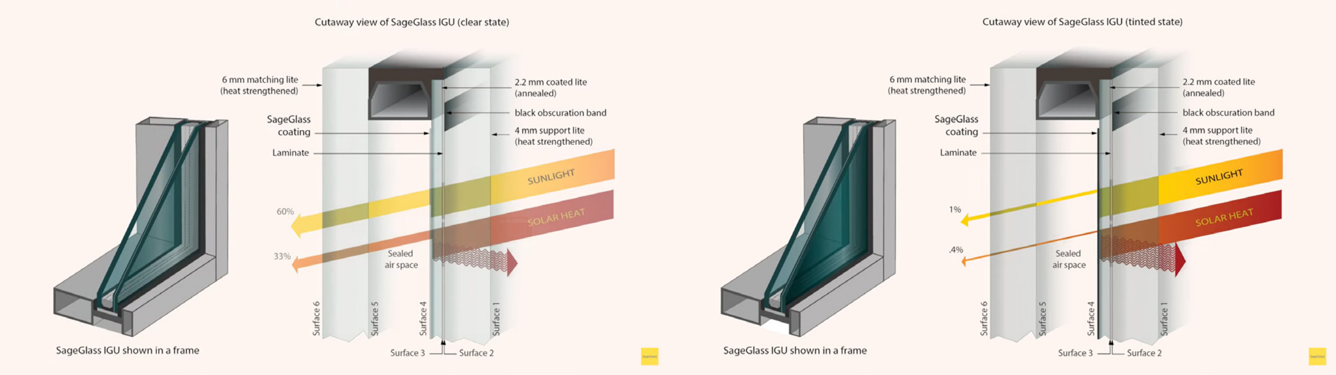


Figure D.2: Cross section of the SageGlass: bleached state (a) and colored state (b). Copyright by SageGlass (2018).

Furthermore, the "Dimmable Aircraft Window" is a product produced by the company: Gentex Corporation (figure D.3). As can be seen in figure D.4, contrary to the SageGlass window, the electrochromic layer ("Electrochromic Panel") is implemented as separate layer at the inside of both windows inside the structural cabin window system. According to the GentexCorporation (2021), the "Dimmable Aircraft Window" improves the flying experience and the aircraft design flexibility while enabling customers and the crew more control over the view outside the windows.

Figure D.3: Dimmable Aircraft Window. Copyright by GentexCorporation (2021).

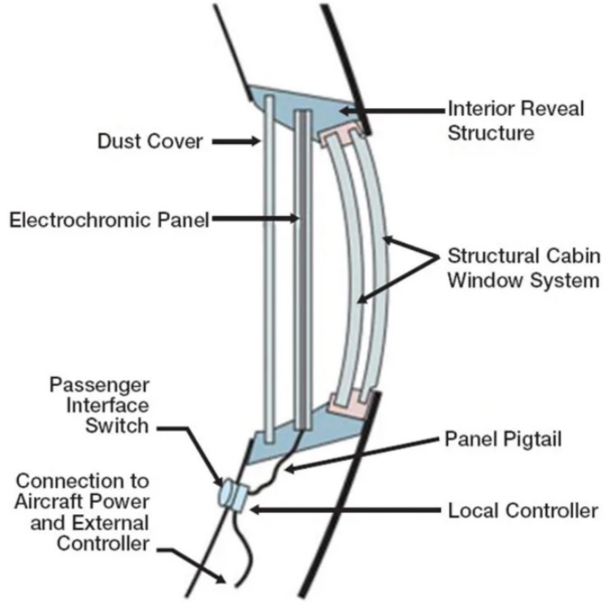


Figure D.4: Cross section of a dimmable window. Copyright by Gentex (2017).

Figure D.5: Dimmable Aircraft Window. Copyright by GentexCorporation (2021).

Finally, the "Converlight Dynamic" is a smart dynamic glass developed by the company ChromoGenics. According to their product portfolio, the Converlight Dynamic is implemented in at least 24 buildings, varying from office buildings to educational or commercial purposes to hotels. For example, as can be seen in figure D.6, it is implemented into windows of the Icehotel of Jukkasjärvi.

Figure D.6: Icehotel- Jukkasjärvi. Copyright by ChromoGenics (2021).

D.2. RAPID PROTOTYPING

Companies such as Ynvisible, RdotDisplays and Prelonic offer rapid prototypes with high flexibility using electrochromic materials. Remarkable is that these companies only focus on the rapid prototyping and are not involved into smart glass applications.

The display design options can be manufactured according the consumers wishes. As RdotDisplays (2021) states: "We will provide support throughout the entire prototyping process with design for mass production in mind". From this it can be concluded that these companies are trying to make the translation from rapid prototyping to implementation within product designs for electrochromic devices. However, these applications seem (for now) to stay in the prototyping phase, as no implementation in products that are on the market can be found. See figure D.7 and D.8 for examples from their websites.

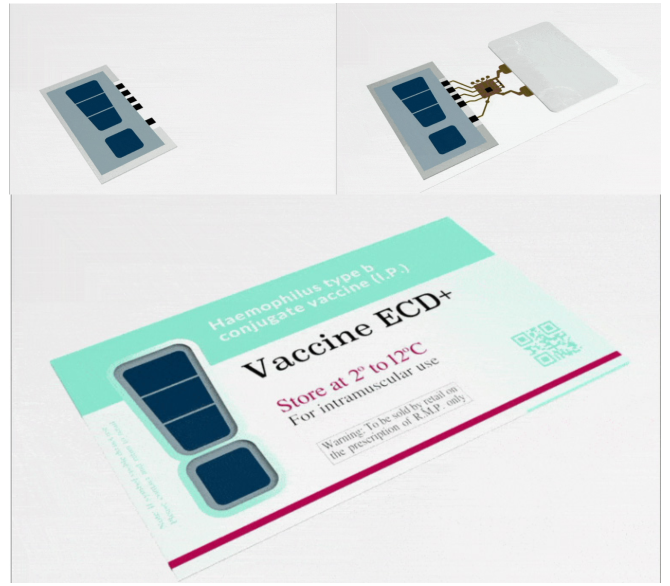


Figure D.8: Vaccine ECD+: easy integration. Copyright by Ynvisible (2020a).

Figure D.7: Prototype manufacturing applications. Copyright by RdotDisplays (2021).

Figure D.9: 7-segment display on paper. Copyright by PrelonicTechnologies (2021).

This page is intentionally left blank

E.1 PRODUCTION METHOD STANDARD VERTICAL ECD

Preparation:

1. Cut the ITO coated PET substrate and encapsulation in the desired shape/size;
2. Cut the files of the EC layer(s) with the vinyl cutter;
   - Remove the parts of the sticker that need to be printed (so you keep the negative);
   - If necessarily, put a FIXME sticker on top of it, so all parts of the sticker will be transfered when removing it;

Electrochromic layer:

3. Place the substrate on the table and attach it with a small piece of masking tape at the top;
   - Check with a multimeter what the ITO coated side of the substrate is;
   - Put the mesh (screen) on top of the substrate and put the weights on the frame;
4. Place the vinyl stickers of the two EC layers on the mesh (T140-T120);
   - Align the sticker and the substrate in the bottom left corner;
5. Screen print both the EC layer on the substrate and on the encapsulation (make sure to use the ITO coated side!);
   - Use your free hand to manually add some pressure on the screen itself around the ECD.
   - Go with the squeegee over the mesh twice immediately after each other so two layers of EC material are applied to the substrate.
6. Let the substrate and encapsulation with the EC ink cure in the oven at 130 degrees for 15 minutes;
7. Clean all tools;

Electrolyte:

8. Place the bi-adhesive on the substrate;
   - Do not remove the top liner of the bi-adhesive spacer.
9. Apply the electrolyte within the adhesive on top of the EC ink;
   - Use an "Injekt F fine dosing syringe" for this.
10. Remove the top liner of the adhesive;
11. Before spreading the electrolyte, put the encapsulation on top of the bottom substrate;
    - Make sure that the ITO layer of the encapsulation touches the electrolyte (upside down).
    - Seal the encapsulation on all sides of the bi-adhesive spacer, but leave one corner open!
12. Spread the electrolyte within the adhesive frame by using a cotton bud;
    - Make sure all the air is left out;
13. When the electrolyte is fully spread, press both substrate on top of each other by sealing the last corner;
    - To completely seal it and evenly spread the electrolyte in the frame, use a spatula.
14. UV curing for about 10 minutes;

Finishing:

15. Cut the corners nicely

E.2 PRODUCTION METHOD STANDARD CO-PLANAR ECD

Preparation:

1. Cut the overhead sheet substrate and encapsulation in the desired shape/size;
2. Cut the files of the EC layer(s) with the vinyl cutter;
   - Remove the parts of the sticker that need to be printed (so you keep the negative);
   - If necessarily, put a FIXME sticker on top of it, so all parts of the sticker will be transfered when removing it;

Electrode:

3. Place the substrate on the table and attach it with a small piece of masking tape at the top;
   - Put the mesh (screen) on top of the substrate and put the weights on the frame;
4. Place the vinyl stickers of the electrodes on the mesh (T74);
   - Allign the sticker and the substrate in the bottom left corner;
5. Screen print the electrodes on the substrate;
   - Use your free hand to manually add some pressure on the screen itself around the ECD;
6. Let the substrate with the electrodes printed on it cure in the oven at 130 degrees for about 15 minutes;
7. Clean all tools;

Electrochromic layer:

8. Place the substrate with the electrodes printed on it on the table and attach it with a small piece of masking tape at the top;
   - Put the mesh (screen) on top of the substrate and put the weights on the frame;
9. Place the vinyl sticker of the EC layer on the mesh (T140-T120);
   - Align the sticker and the substrate in the bottom left corner;
10. Screen print the EC layer on the substrate ;
    - Use your free hand to manually add some pressure on the screen itself around the ECD.
    - Go with the squeegee over the mesh twice immediately after each other so two layers of EC material are applied to the substrate.
11. Let the substrate with the EC ink (and electrodes) cure in the oven at 130 degrees for 15 minutes;
12. Clean all tools;
13. Check whether there is a current flow between the two layers;
    - If yes, adjust the parting line between the two EC layers by using a knife.

Electrolyte:

13. Place the bi-adhesive on the substrate;
    - Do not remove the top liner of the bi-adhesive spacer.
14. Apply the electrolyte within the adhesive on top of the EC ink;
    - Use an "Injekt F fine dosing syringe" for this.
15. Remove the top liner of the adhesive;
16. Before spreading the electrolyte, put the encapsulation on top of the bottom substrate;
    - Make sure that the ITO layer of the encapsulation touches the electrolyte (upside down).
    - Seal the encapsulation on all sides of the bi-adhesive spacer, but leave one corner open!
17. Spread the electrolyte within the adhesive frame by using a cotton bud;
    - Make sure all the air is left out;
18. When the electrolyte is fully spread, press both substrate on top of each other by sealing the last corner;
    - To completely seal it and evenly spread the electrolyte in the frame, use a spatula.
19. UV curing for about 10 minutes;

Finishing:

20. Cut the corners nicely

F PRODUCTION: SCREENPRINTING

As it is more accessible and easy to perform within the chemical lab of the faculty of Industrial Design Engineering (see figure F.1), all ECDs within this research are created by ***screen printing*** using ***vinyl stickers*** as stenciling technique. As safety measure, when working in this chemical lab, a lab coat, safety glasses and gloves are worn at all times.

Figure F.1: Chemical lab at the Faculty of Industrial Design Engineering.

Step 1: Preparation. Starting with the design of the images to be displayed. When designing the images to be displayed, the "Basic Rules for Display Design" (Ynvisible, 2020a) should be taken into account. The minimum width of the bi-adhesive spacer is set at 5mm, with a minimum distance of 3 millimeter between the electrolyte and the conductive tracks, see figure F.2. The (two) images displayed within the EC material should have a similar active area. An active area is the area of the primary and secondary electrochromic layer that is covered by the electrolyte; i.e. the area that is possible to change its color.

After using the vinyl cutter (figure F.3), carefully remove all parts of the stencil by using a needle and attach the sticker to the mesh of the screen. Besides this, assure that the substrate and encapsulation are cut into the right size.

Step 2: Screen printing the conductive tracks. The second part of the process is to screen print the conductive tracks. Remark: when a vertical ECD is created using a conductive substrate and/or encapsulation, this step is skipped. As in figure F.4 can be seen, within this research (primarily) the "SunChemical Silver Paste: C2120918P1" is used as material for the conductive tracks and a mesh of 54 T. After screen printing the silver paste on the substrate, it has to dry in the oven for approximately 5 minutes at 130 degrees.

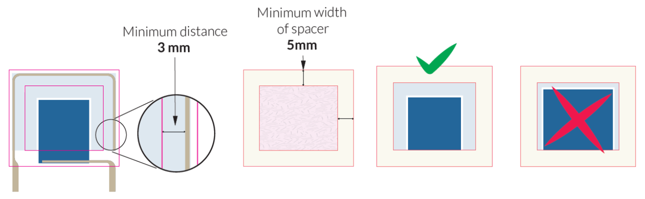


Figure F.2: Design Guidebook: "Basic Rules for Display Design". Copyright by Ynvisible (2020a)

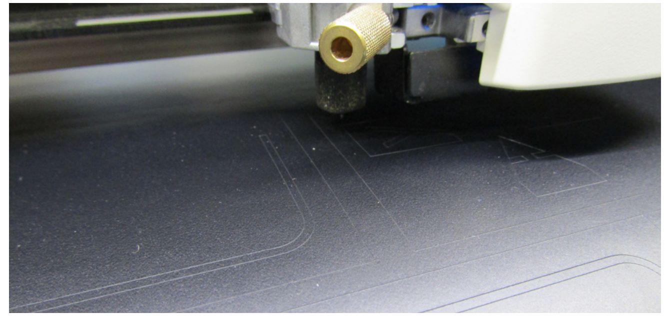


Figure F.3: Vinyl cutter.

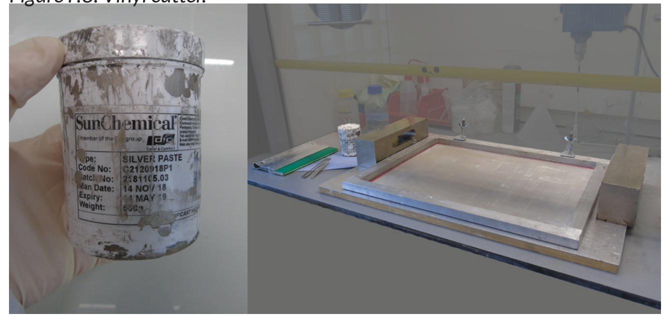


Figure F.4: Conductive tracks: materials

Step 3: Electrochromic layers. After the conductive tracks are dried, the electrochromic layer can be printed on top of it. Besides the Ynvisible electrochromic ink, a mesh of 120 T is required (figure F.5). Important to note while screen printing the electrochromic layer on top of the conductive tracks; is that at all points that a transition in surface occurs, the electrochromic material has difficulties with its adhesion that result into irregularities, as can be seen in figure F.6. To prevent this, the conductive tracks should be oriented parallel to the direction of the squeegee to ensure a smooth connection between the EC layer and the conductive tracks, see figure FIXME.

After screen printing the EC layer, the substrate should be dried in the oven at 130 degrees for 5 minutes too. Important for a co-planar ECD is that; after the curing, the conductivity between the two EC layers should be checked. If there is a current flow between the two layers, the display will have a short circuit and not function, so the parting line between the two layers should be adjusted by using a knife; i.e. remove the EC material (see figure F.7).

Step 4: Electrolyte. After the electrochromic layer is dried, the bi-adhesive spacer (a double sided adhesive tape) can be placed on top of it. After this, the electrolyte can be attached by using the "Injekt F fine dosing syringe" and a cotton bud, see figure F8. As can be seen in figure F.0-a, it is important that after applying the encapsulation to the bi-adhesive spacer, it will be closed for 90% (i.e. leave the left top corner open). Gently spread the electrolyte in the bi-adhesive spacer and try to remove all air through the corner that is left open. When all the electrolyte is spread, close the corner and spread the electrolyte equally by using a spatula. When air is left inside the electrolyte, the EC material will not color at that point, see figure F.9-b.

Step 5: Finishing. After the electrolyte has cured for approximately 1 minute underneath an UV lamp with a power of 250 mW/cm2 and 5 cm distance (Ynvisible, 2020b), the edges of the ECD can be cut and then the ECD is finished and ready for use.

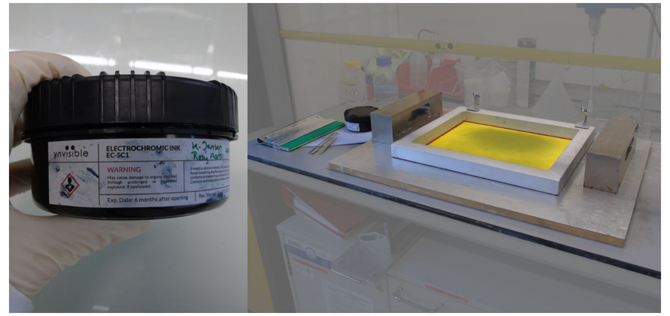


Figure F.5: Electrochromic layers: materials.

Figure F.6: Orientation of the conductive tracks: good (a) and irregularities (b).

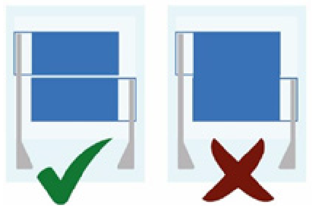


Figure F.7: Primary and secondary EC layer of a co-planar display: good (a) and short circuit (b).

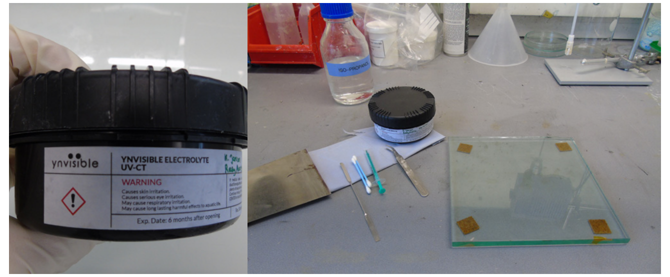


Figure F.8: Electrolyte: materials

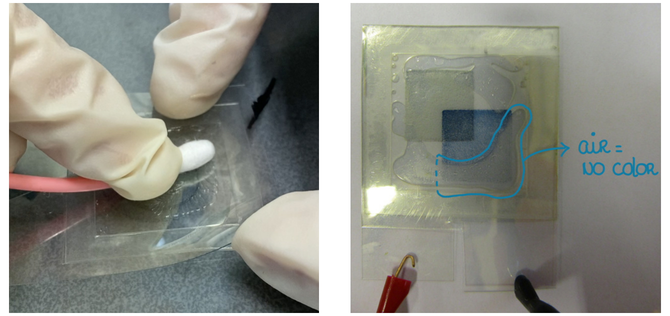


Figure F.9: Gently spread the electrolyte within the ECD (a) and air left in the electrolyte (b).

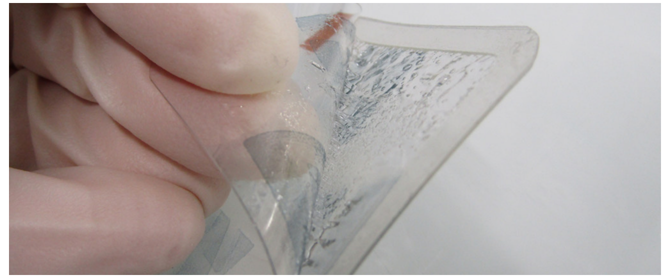


Figure F.10: Opening the ECD after the electrolyte is cured. It is still liquid but with a slightly higher viscosity.

G MATERIAL OF THE ECDs

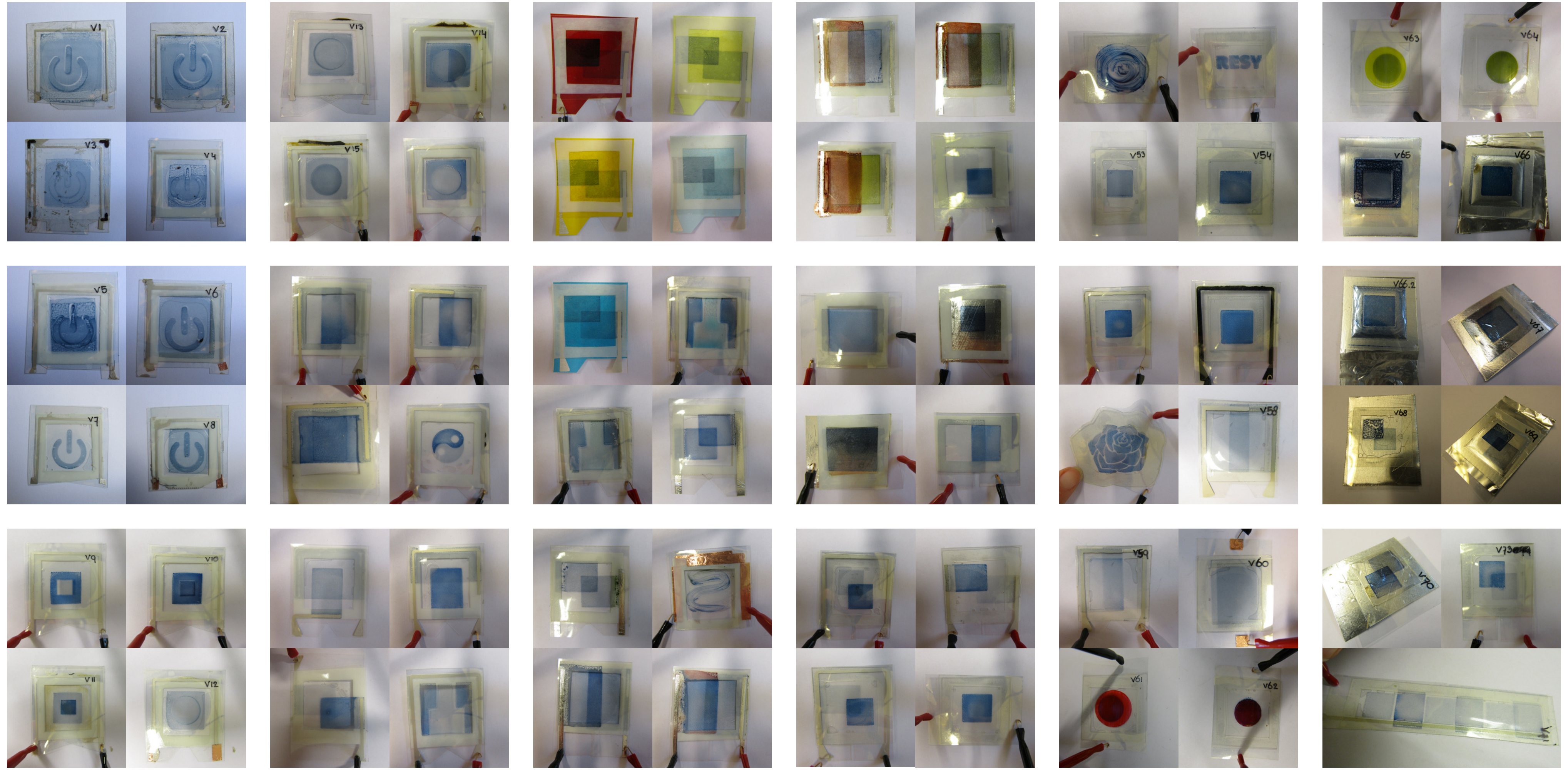
Layer	Material used	Notes
Substrate/Encapsulation	PET coated ITO	Conductive
	PET overhead sheets	Insolating
	Cardboard	Insolating Appears that the cardboard absorbs the electrolyte.
	Conductive tape (mirror)	Conductive
Conductive tracks	None	Only possible for a vertical display.
	Ynvisible electrochromic ink	Make sure the tracks are wide, so possible cracks created while screen printing don't influence the conductivity.
	Silver paste…	Apply either by screen printing with a mesh of FIXME or by using a vinyl sticker and a knife. Hard to remove from the mesh.
	Bare conductive paint	Black of color. Easy to apply with a paintbrush but also easy to remove when dried.
	Copper foil tape (0.07 mm)	Thicker than the previous options, which can cause irregularities while screen printing the EC layer.
Electrochromic layer	Ynvisible electrochromic ink	
Bi-adhesive spacer	3M 467MP, 200MP adhesive (FIXME mm)	Too thin, conductive tracks broke while removing the top liner.
	TESA carpet tape (0.17 mm)	Not transparent.
	TESA Powerbond (0.49 mm)	Transparent. But too thick and hard to handle.
	3M 467MP, 200MP adhesive (0.22 mm)	
Electrolyte	Ynvisible electrolyte	

Table FIXME: Materials used for the different layers of the ECDs

This page is intentionally left blank

H.1 VERTICAL DISPLAYS

The nomenclature aligns with the vertical (ECD-V-#) or co-planar (ECD-C-#) stacking sequence with incremental numbering.



H.2 CO–PLANAR DISPLAYS

The nomenclature aligns with the vertical (ECD-V-#) or co-planar (ECD-C-#) stacking sequence with incremental numbering.

I OPTIMIZATION OF THE LAYERS

Layer	Objective	Action plan	Outcome
Substrate	Insulating	PET overhead sheets	ECD-C-60.0
		PET overhead sheets: curvature	ECD-C-60 till ECD-C-63
		Glass jar: curvature	ECD-C-66 till ECD-C-69
		Paper/Cardboard: curvature	ECD-C-64 and ECD-C-65
		Textile	ECD-C-71.1
		Textile: water resistant (Smart fabrics interface UV-IF1004)	ECD-C-71.2 and ECD-C-71.3
	Conductive (substrate with conductive and counter electrode)	PET coated ITO vertical display	ECD-V-53 and ECD-V-54
		Aluminium FIXME mm	ECD-V-65 and ECD-V-68
		Aluminium foil	ECD-V-66 and ECD-V-69
		Conductive tape	ECD-V-67 and ECD-V-70
Conductive layer	Alternative materials	None	ECD-V-53 and ECD-V-54
		Ynvisible Electrochromic ink	ECD-C-46, ECD-C-47
		Silver paste	ECD-V-55 ECD-C-44, ECD-C-45, ECD-C-48
		Conductive paint (Bare conductive electric paint)	ECD-V-56 ECD-C-49
		Conductive tape	ECD-V-50
	Influence of the layer order	Substrate- conductive tracks- EC	ECD-V-58 ECD-C-51
		Substrate- EC- conductive tracks	ECD-V-59 ECD-C-52
	Influence of the orientation of the conductive tracks	Conductive tape 180 degrees	ECD-C-58 and ECD-C-59
		Conductive copper tape 180 degrees	ECD-V-60
Electrochromic layer	Color intensity	Discover the influence of different layer thicknesses of EC ink in one ECD by screen printing and curing them in between.	ECD-V-12 till ECD-V-13
		Discover the influence of overlap of the two EC layers	ECD-V-12, ECD-V-14 and ECD-V-15
Bi-adhesive spacer	n/a		
Electrolyte	n/a		

I.1. SUBSTRATE

I.1.1. PET OVERHEAT SHEETS

Within ECD-C-60 till 63 there is experimented with curved ECDs. Four ECDs are created with a rounded curvature, a corner of 60 degrees and two fully rounded ECDs, see figure FIXME. For the rounded ECD (ECD-C-60) a glass jar with a circumference of 200 mm was used, for the corner of 60 degrees a hexagonal glass jar and for the two fully rounded a glass bottle with a circumference of 100 mm.

Figure I.1: Substrates attached to the glass objects.

The curvature was applied to the ECD immediately after curing the EC layer. So when the substrate with conductive tracks and EC layer was taken out of the oven (after 15 minutes of curing at 130 degrees), the substrate was attached to a glass object with masking tape in order to mirror its curvature, see figure I.1. The glass object with the substrate attached to it was put again in the oven for about 10 minutes after which it cooled down. When removing the substrate from the object, all four ECDs mirrored the curvature.

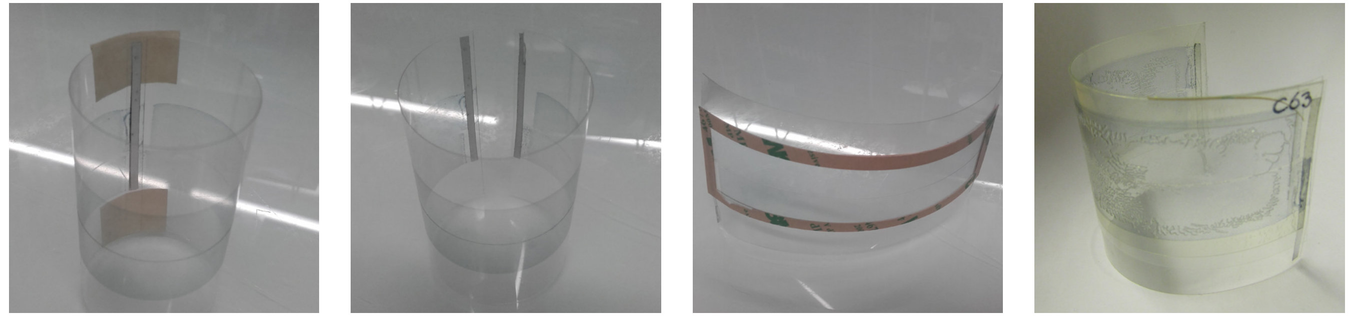


Figure I.2: ECD-C-63, after removing the object (a), after removing the masking tape (b), after applying the bi-adhesive spacer (c) and after putting masking tape on it again (d).

However, when applying the bi-adhesive spacer to the bended substrates, they all moved back to almost flat, see figure I.2 for ECD-C-63.

When looking at the results of all four ECDs, applying the electrolyte on a rounded to straightened surface proved to be more difficult than expected; irregularities occured (figure I.3). After putting the right amount of electrolyte on it and trying to give back all curvatures to the ECDs, none of them operated at first sight. However when attaching ECD-C-63 to the potential, after a while it seemed to color, see figure I.4, the switching time is just so slow that it is barely noticeable, e.g. minutes rather than seconds. The secondary EC layer on the other hand, does not color at all. It is difficult to say what exactly is the issue, but it is assumed that it is because the electrolyte keeps spreading over the curvature.

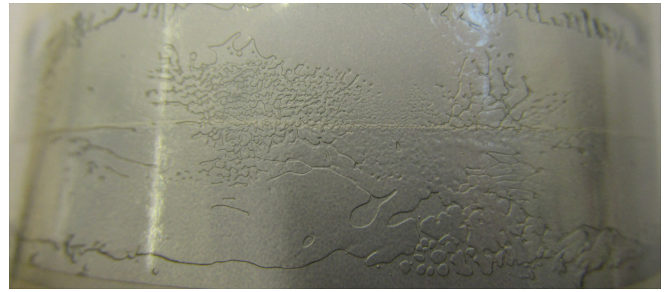


Figure I.3: Irregularity of the electrolyte applied to ECD-C-63

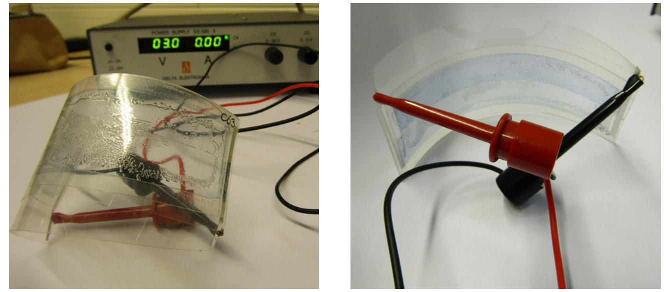


Figure I.4: ECD-C-63: voltage applied (a) and Primary EC layer (b)

I.1.2. GLASS JAR

Within ECD-C-66 till ECD-C-69 there is experimented with a glass jar as curved substrate. Four ECDs are created on a hexagonal glass substrate. This experiment elaborates further on the previous one, as the substrate is bended from the start of the experiment. The procedure for creating these four ECDs was as follows: first the conductive tape was attached to the flat substrate after which the EC layer was applied to it by means of using the vinyl sticker as a stencil and painting the EC material with a brush. After curing in the oven at 130 degrees for at least 15 minutes, the bi-adhesive spacer was put on the substrate and the electrolyte was added which is closed by an encapsulation of a PET overhead sheet, see figure FIXME.

As can be seen in figure I.5, the encapsulations are attached to the substrate by using masking tape, this is done since the encapsulation releases itself from the bi-adhesive spacer, allowing the electrolyte to leak. Besides this, spreading the electrolyte has proven to be hard on this substrate, although the substrate was cleaned, the electrolyte had still problems with its adhesion. As a result of these two factors, all four ECDs do not function.

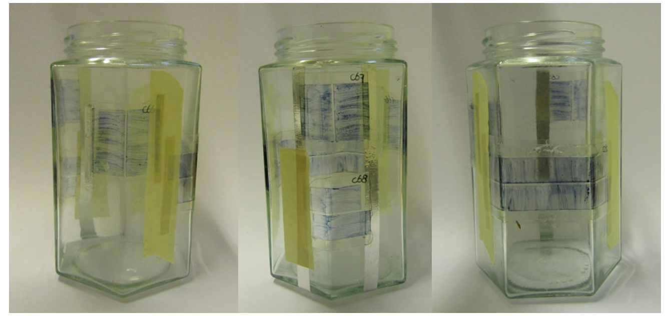


Figure I.5: ECD-C-66 (a), ECD-C-67 (b-top), ECD-C-68 (b-bottom) and ECD-C-69 (c)

I.1.3. TEXTILE

First of all, screen printing on textile is proven to be difficult. As can be seen in figure I.6-a, the EC layer is not evenly distribute on the textile, so the print is adjusted by using a brush, which resulted into a dark blue bleached layer. Furthermore, when applying the electrolyte for all three ECDs, it leaked trough. For ECD-C-71.1 that was expected since it was just plain cotton, however ECD-C-71.2 and ECD-C-71.3 are made waterproof by using "Smart Fabric Inks: Interface: UV-IF1004".

At last, ECD-C-71.1 is the only ECD that operates. Although this operation is barely noticeable by the human eye since the print is already dark, see figure I.8.

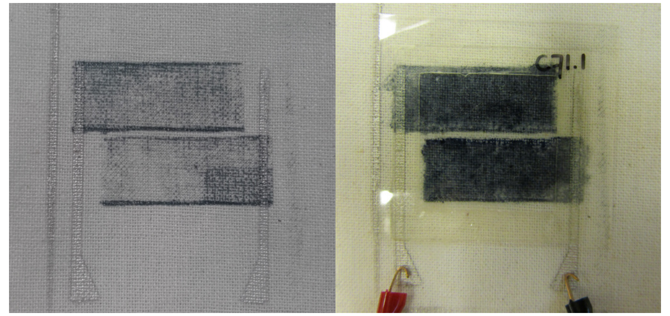


Figure I.6: ECD-C-71.1 after screen printing (a) and after adjusting by using a brush (b).

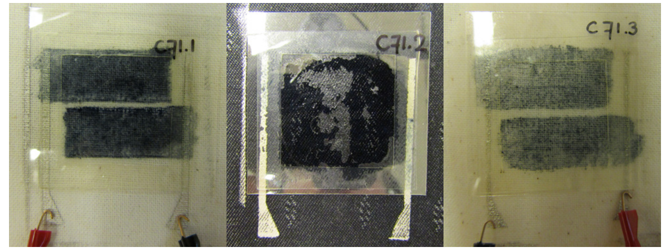


Figure I.7: ECD-C-71.1 Cotton (a), ECD-C-71.2 waterproof printed cotton (b) and ECD-C-71.3 waterproof cotton (c).

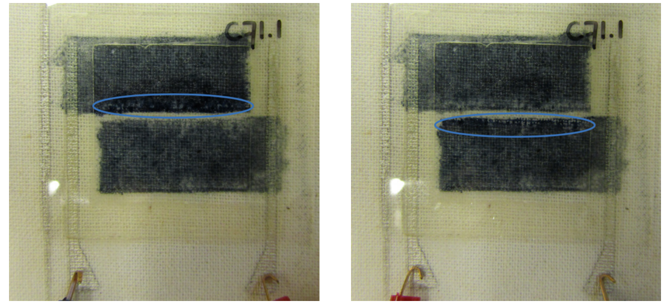


Figure I.8: ECD-C-71.1 Primary EC layer (a) and Secondary EC layer (b).

I.1.4. CARDBOARD

When analyzing the use of cardboard as a substrate, it appeared that the electrolyte is (slightly) absorbed by the cardboard, since both ECDs do not operate and the electrolyte is spread unevenly, although the right amount is applied. See figure I.9 for both ECDs using cardboard as substrate.

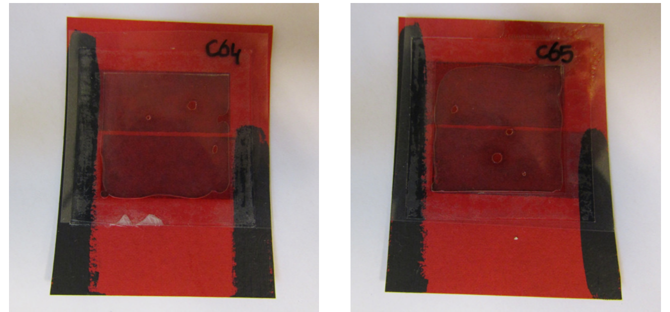


Figure I.9: Cardboard substrate: ECD-C-64 (a) and ECD-C-65 (b).

I.2. ELECTRODES

I.2.1. ALTERNATIVE MATERIAL

With ECD-V-53 till ECD-V-56 and ECD-C-44 till ECD-C-50 the influence of different (conducting) materials as conductive layer on the switching time of the ECD is examined. In table I.1 an overview of the ECDs created with the corresponding materials and switching time are displayed.

As aforesaid, the switching time of an ECD heavily depends on the size of ECD, electrolyte used and size of the image displayed. The size of the ECD and size of the image displayed is kept as a constant for all displays. See figure I.10 and I.11, for the images displayed for the vertical and co-planar displays. The electrolyte used is the Ynvisible electrolyte, however the distribution of this electrolyte could slightly differ per ECD, as at this point of the research the "Injekt F fine dosing syringe" was not in stock. Since all ECDs are created only once, no significant conclusion could be drawn according to this, it only should function as an impression for further research.

All switching times from table FIXME are analyzed looking frame for frame to a movie of the ECD coloring. Starting with the vertical ECDs, the switching time from colored to bleached ('removing the image') is really small compared to all colored switching times. And it appears that using only one conductive layer: ITO coated substrate and 'none' for the conductive tracks works optimal. The conductive paint only increases the switching speed a little. For the co-planar ECDs on the other hand, has the conductive paint relative high switching times. Striking is that the colored state_1 (primary EC layer) and colored state_2 (secondary EC layer) switching speeds differ per ECD, although the same design is used. For this it can be concluded that using the electrochromic material itself as conductive layer would be a good option, since it gave the most stable switching time for both layers.

Material silver tracks	Vertical display		Co-planar display	
None (single layer)	ECD-V-53	Bleached: 00.12s Colored: 03.06s	~~ECD-C-44~~ ~~ECD-C-45~~	n/a
None (double layer)	ECD-V-54	Colored_1: 03.50s Colored_2: 03.58s	n/a	-
Ynvisible EC ink	n/a	-	ECD-C-46 ~~ECD-C-47~~	Colored_1: 07.05s Colored_2: 07.13s
Silver paste	ECD-V-55	Colored_1: 05.53s Colored_2: 07.01s	ECD-C-48	Colored_1: 01.56s Colored_2: 09.04s
Conductive paint	ECD-V-56	Colored_1: 02.42s Colored_2: 01.51s	ECD-C-49	Colored_1: 07.48s Colored_2: 04.50s
Conductive tape	n/a	-	ECD-C-50	Colored_1: 08.44s Colored_2: 06.01s

Table I.1: ECDs created and their corresponding material for the silver tracks and switching time.

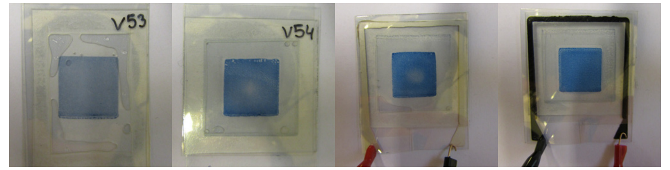


Figure I.10: Vertical display: None (a), none (b), silver paste (c) and conductive paint (d).

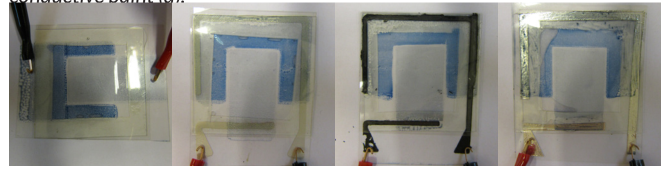


Figure I.11: Co-planar display: Ynvisible EC ink (a), silver paste (b), conductive paint (c) and conductive tape (d).

I.3. SWITCHING SPEED

From ECD-C-1 till ECD-C-7, it can be concluded that the bigger the distance between the two EC layers, the lower the switching speed. However, a distance of 0.5 mm resulted into merging of the two layers, through which the ECD didn't operate. So it is safe to say that a distance of 1 mm between the two EC layers would be the optimal distance for a fast switching speed and it will make sure that the layers won't merge into one layer, see figure I.12.

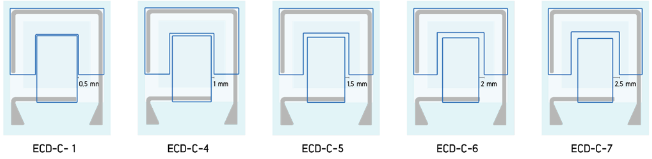


Figure I.12: Optimizing the switching speed: ECD-C-1 till ECD-C-7.

I.4. EXPERIMENT WITH EFFECTS

I.4.1. VOLTAGE FLOW

In the previous experiments a color flow was observed, the influence of the applied potential is explored to see whether a voltage flow can be created. Eight different designs were researched, see figure I.13. In the end, they all were experiencing a color flow but this flow was not directly related to the voltage. Since a vertical display is already activated at 1.5V and the electrolyte turns yellow beyond 3V, leaves us with a frame of 1.5 V for a vertical display. Applying more and more voltage to a vertical display increases the color intensity from blue to bright blue, so that is the most optimal of a voltage flow (voltage color intensity) that is reached.

Concluded, ECD-C-76 is the ECD with the biggest potential of a voltage flow since a flow of squares is created when the potential is applied to a different square. The positive of the potential is applied to a square that is in its bleached state, causing the square where the negative is attached to, to color. As, the square that is attached to the positive is a new square, the color adds up instead of flow between the squares. See figure I.14. In a product design, this could be achieved by programming that the higher the voltage applied, the more squares are sent a potential to.

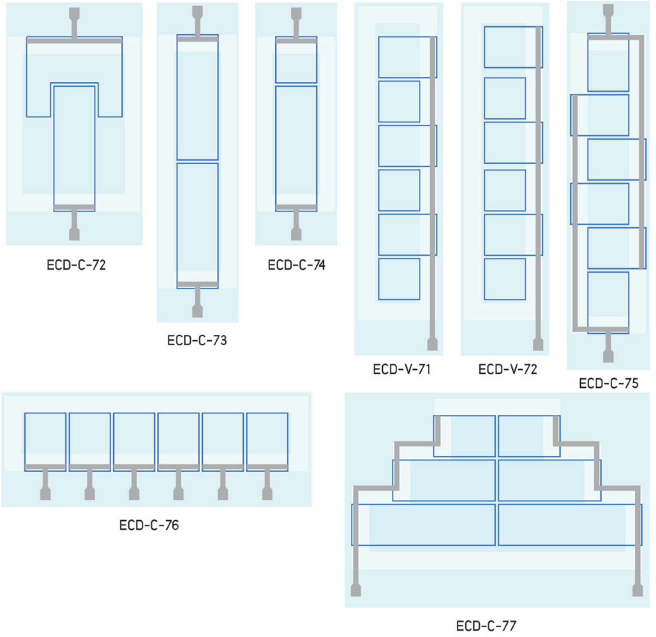


Figure I.13: Voltage flow design of ECD-C-72 till -77 and ECD-V-71 and 72.

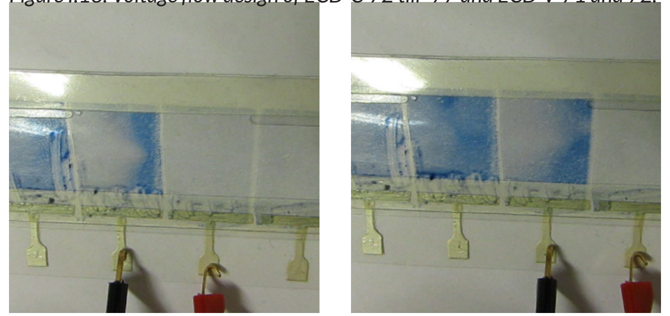


Figure I.14: ECD-C-76: Voltage flow.

Interesting to note is that the design of ECD-C-76 also opens a new opportunity, namely the influence of an EC layer that is not attached to the potential. As can be seen in figure I.15-a, the square attached to the positive (red) of the potential is already colored, however when attatching the negative to another square, the square in the middle of these two starts to color. Through this, EC layers that are not connected to the potential can be manipulated.

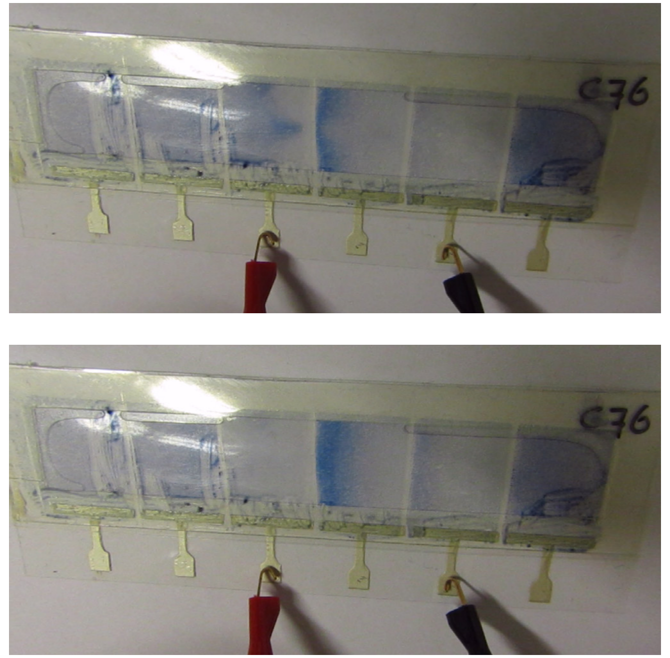


Figure I.15: ECD-C-76: Voltage flow, manupulating others.

I.4.1. USE OF COLOR: DIFFERENT COLORS

As can be seen in figure I.16, it was assumed that the ***colored substrate*** would influence the starting coloring of the ECD, namely: red substrate: purple starting color and yellow substrate: green starting color. However, using a colored cardboard as substrate for vertical ECDs did not result into the expected colored outcome. The color of the cardboard only influenced the color of the EC material in its darkness. To elaborate more on this darkness it could be clearly seen that the EC material printed on the dark red and dark blue color (see figure I.17-a and I.17-e) resulted into a darker blue for the EC material and the ECDs where the EC material was printed on the bright-and-darker yellow and light blue resulted into a lighter blue for the EC material (see figure I.17-b, -c and -d). On the contrary, the colored substrate didn't influence the color itself as was assumed.

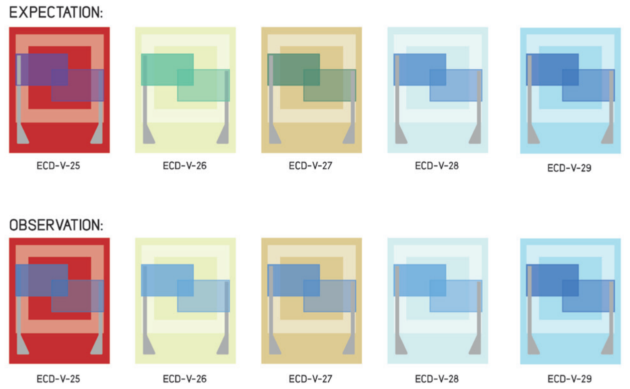


Figure I.16: Expectation and observation of the coloring of ECD-V-25 till -29.

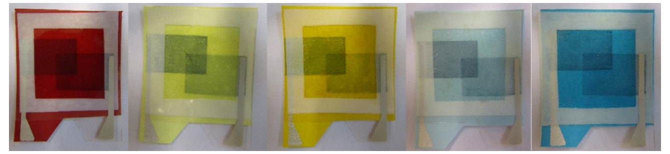


Figure I.17: Observations of the coloring of ECD-V-25 till -29.

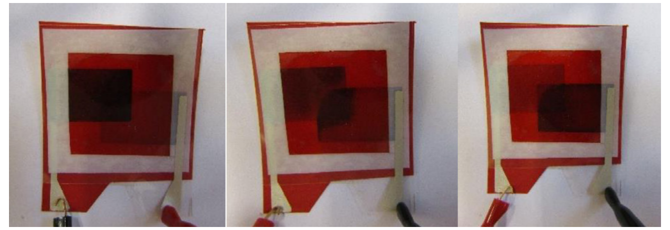


Figure I.18: ECD-V-25: Primary EC layer (a), coloring (b) and Secondary EC(c).

On top of this, of these five ECDs, only ECD-V-25 operates. When combining this with the results from ECD-C-64 and ECD-C-65 (also cardboard substrate), it indeed can be concluded that the ECD has difficulties since it is assumed that the cardboard absorbs the electrolyte.

Based on the art movement the pointillism, the assumption is made that when two colors are placed closely next to each other or on top of each other, the illusion of a mixed color can be perceived by the human eye. Since red and blue mix to purple and yellow and blue to green, these two colors are tried to be achieved. Thus there is experimented with a ***painted layer*** underneath the EC layer, see figure I. 19

As can be seen in figure I.20, the left ECD (ECD-V-62 and ECD-V-64) appear to be more of purple and green. The difference is less than expected, but still present. It appears that when the two colors are 100% placed on top of each other, the hint of a mixed color is given. However, when the area of one of the two colors is larger, less mixing appears.

In figure I.21, a co-planar ECD is created with the same idea, although now a clear difference can be seen between the bleached state of a layer and the colored state of a layer. Important to note is that the blue layer in the middle is also first painted with blue acrylic paint.

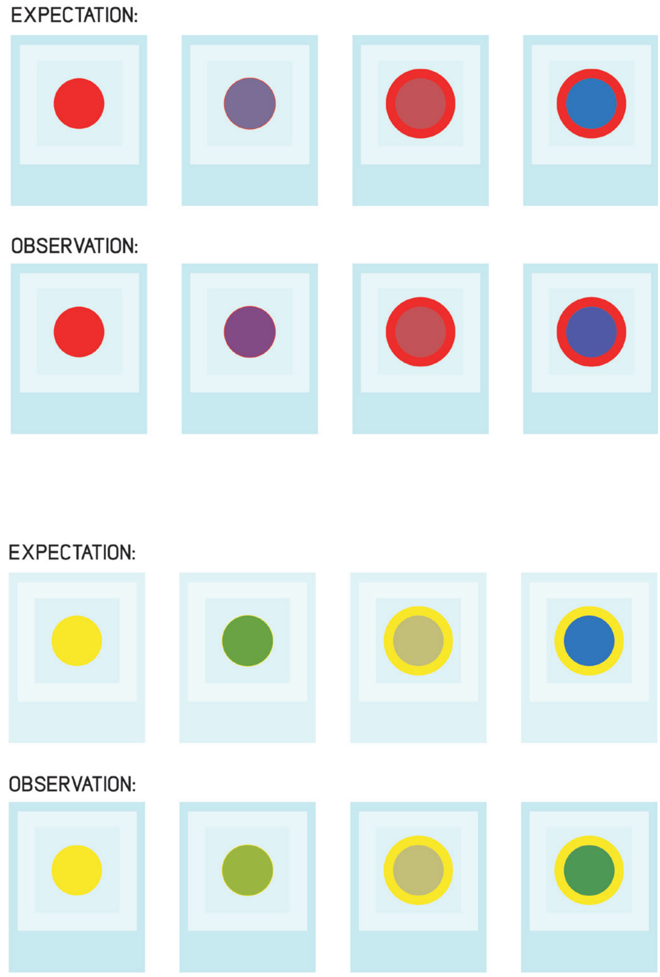


Figure I.19: Expectation and observation of the colors of ECD-V-61 till -64.

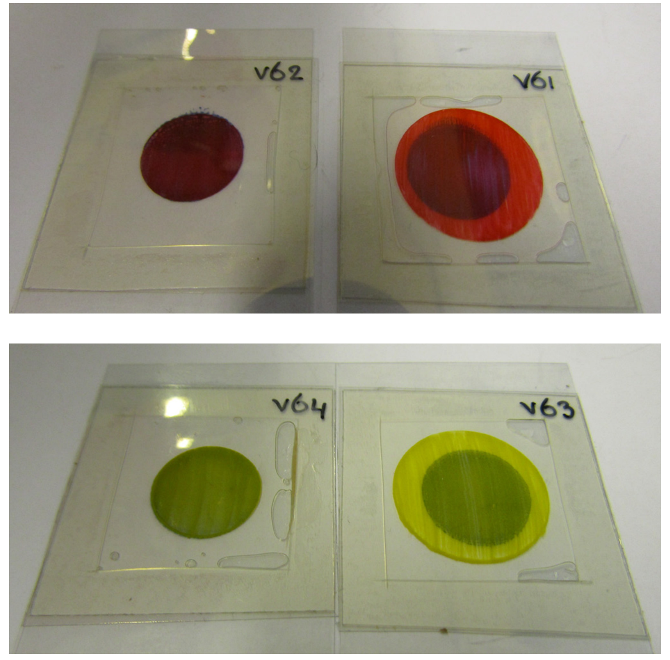


Figure I.20: Colored state of ECD-C-61 till -64.

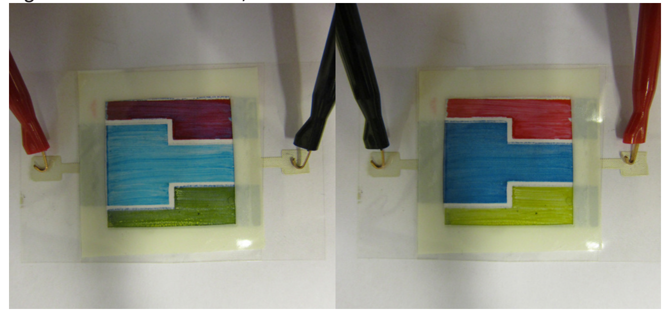


Figure I.21: Different colors of ECD-C-34. Primary EC layer (a): purple-blue-green (a) and secondary EC layer: red-blue-yellow (b).

The 'Ynvisible electrochromic ink' is mixed with other colored materials. Namely: acrylic color paint, ecoline, coloring pigment, food coloring, aquarelle paint pigment and pastels. As can be seen in figure I.22, four ECDs are created for each material: a co-planar and vertical ECD with the primary EC layer (left) mixed with red and the secondary EC layer (right) mixed with yellow and a co-planar and vertical ECD with the primary EC layer (left) mixed with white and the secondary ECD layer (right) not mixed. Since of all mixtures only two ECDs are created, no significant conclusions could be drawn from this, since the cause of defective could also be influenced by poor screen printing of the layer or unevenly distribution of the electrolyte. Yet, the two ECDs give a good impression of the possibilities.

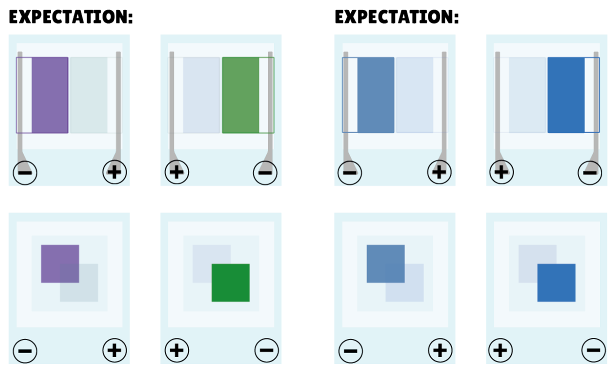


Figure I.22: Expectation of mixing color with the Ynvisible electrochromic ink. Red/yellow (left) and white/none (right).

As can be seen in figure I.23, the Ynvisible electrochromic ink and ***acrylic paint*** mix to a solid color. Yet, the co-planar ECD and primary EC layer of the vertical ECD do not operate. Only the secondary EC layer of the vertical display (ECD-V-74) colors slightly to blueish green (see figure I.23-b). It is expected that the addition of the acrylic paint layer disrupts the electron distribution/transfer.

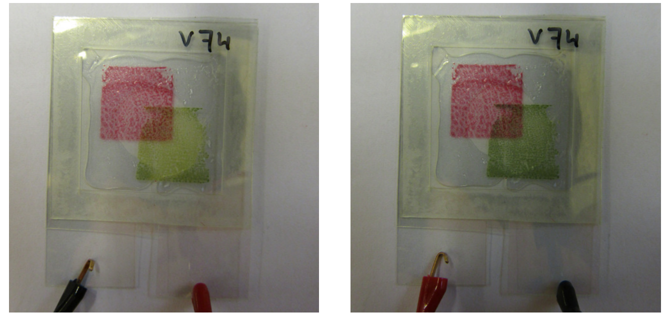


Figure I.23: ECD-V-74: Primary EC layer (a) and Secondary EC layer (b).

Ecoline mixes with the EC material to solid colors. Although the color intensity of these colors in the bleached state is less than for the acrylic paint. When looking at figure I.24, mixing red ecoline results into a hint of purple when colored and orange/red when bleached. Mixing yellow, does not influence the color; blue when colored and yellow in the off state.

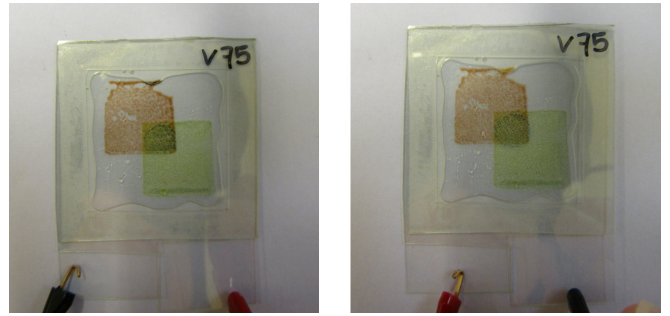


Figure I.24: ECD-V-75: Primary EC layer (a) and Secondary EC layer (b).

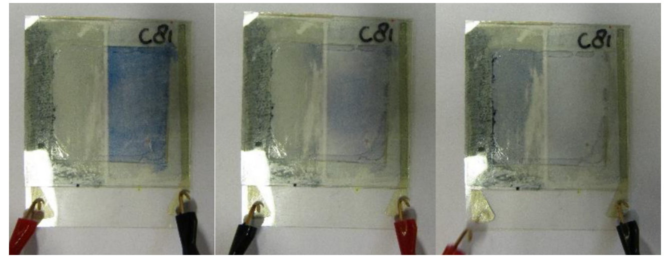


Figure I.25: ECD-V-75: Primary EC layer (a) color flow (b) and secondary EC (b).

Mixing white ecoline results into an translucent appearance in bleached state and a translucent blue colored state. This translucent blue has a notable lower color intensity than the unmixed electrochromic color as can be seen in figure I.25-a and I.25-c. The fact that the electrochromic layer that is mixed with the white ecoline is not printed equally combined with the translucent appearance, gives an interesting effect to the coloring as can be seen in figure I.25-b.

Pigment and the electrochromic ink do not mix to a homogeneous solution. As clearly can be seen in figure I.26-c: ECD-V-77, the solution is still a granular dispersion. This granular dispersion resulted into unevenly screen printing of the EC layers, causing the ECDs not to function fully. Remarkable is that both the ECDs mixed with the red and yellow pigment do not function at all, while the ECDs mixed with the white pigment operate optimal. As can be seen in figure I.27, the white pigment resulted into a translucent color for the bleached state and translucent blue when colored, just like the white ecoline.

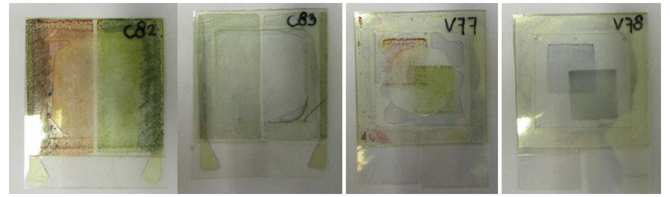


Figure I.26: 'Ynvisible electrochromic ink' mixed with coloring pigment.

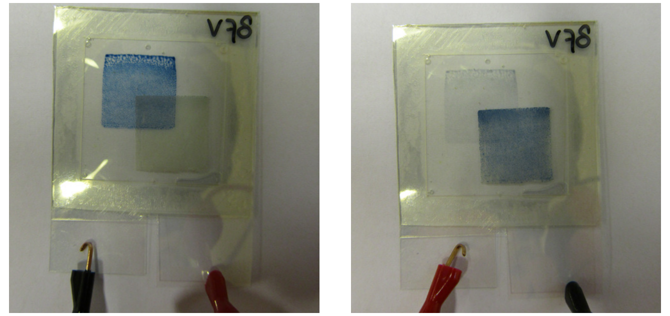


Figure I.27: ECD-V-78: Primary EC layer (a) and Secondary EC layer (b).

Mixing ***aquarelle pigment*** with the 'Ynvisible electrochromic ink' results into pastel colored hints of red and yellow, although they almost appear more as pastel purple and green in the bleached state, see figure I.28. The mixture does not influence the intensity of the color when colored, since this is the original bright blue color. The same applies to the white mixture.
This is an interesting aspect as the starting color is a different pastel color, but the blue does not lose its bright blue color intensity, see figure I.28 and I.29.

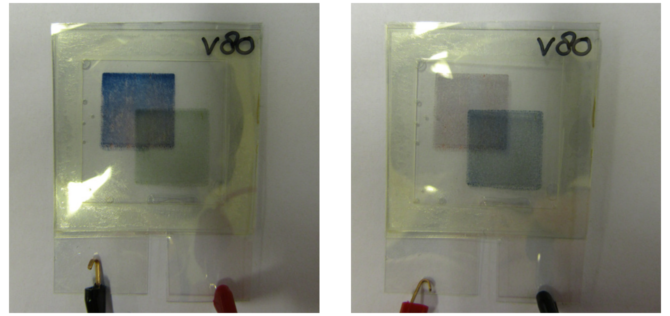


Figure I.28: ECD-V-80: Primary EC layer (a) and Secondary EC layer (b).

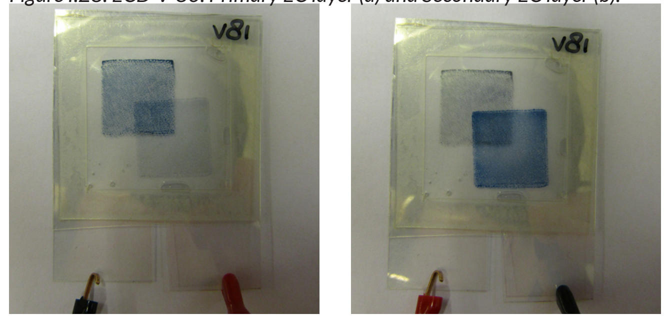


Figure I.29: ECD-V-81: Primary EC layer (a) and Secondary EC layer (b).

Mixing ***chalk*** with the 'Ynvisible electrochromic ink' resulted into different results based on its homogeneity of the mixture. Which as expected influences the operation of the ECD. As can be seen in figure I.30-a and I.30-c, the red chalk is not mixed well with the electrochromic material, resulting into a granular mixture. Not surprisingly is thus that these layers do not color. the other layers are mixed well and thus functioning well. As can be seen in figure FIXME, the yellow mixture is yellow in the bleached state and bright blue when colored and the white appears to be translucent in the bleached state and also colors bright blue.

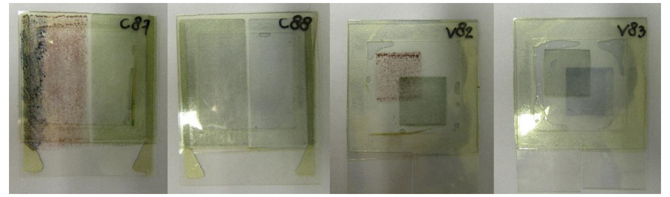


Figure I.30: 'Ynvisible electrochromic ink' mixed with chalk.

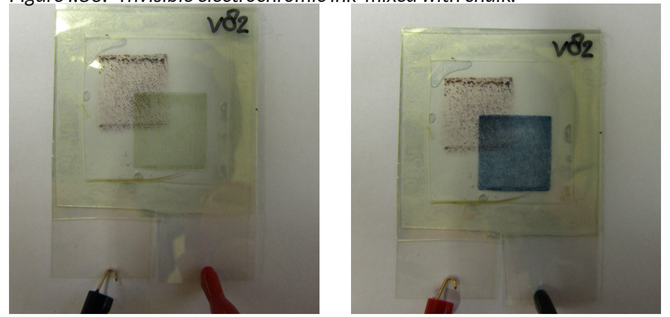
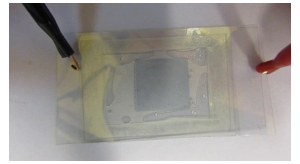


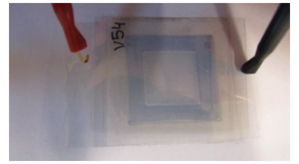
Figure I.31: ECD-V-82: Primary EC layer (a) and Secondary EC layer (b).

This page is intentionally left blank

J USER RESEARCH 1: QUESTIONS

Test 1


Prototype 1


Prototype 2

Test 1

1. Which of the two prototypes is more appealing to you and why?

Prototype 2: More happening. Takes longer and draws attention. I feel geintegreerd.
Prototype 2: More happening. I'm surprised that's possible.
Prototype 2: Looks more complicated.
Prototype 2: More surprising, more tension.
Prototype 2: Playful.
Prototype 2: More interesting change.

2.. What kind of associations do you have with both prototypes?

Prototype 1: Nothing.
Prototype 1: Next image of a video.
Prototype 1: Leaf.
Prototype 1: Blinding windows.
Prototype 1: Window, opening (tussenruimte).
Prototype 1: Dressing room
Prototype 2: Fade out of an old television screen.
Prototype 2: Frame, picture frame, focus on the middle.
Prototype 2: Water flowing.
Prototype 2: Crowd management.
Prototype 2: Playful
Prototype 2: The news of the old days.

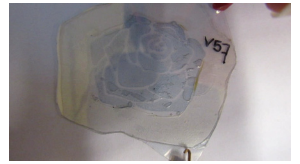
3. What kind of associations does prototype 2 evoke for you?

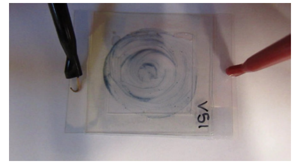
1 2 3 4 5 6 7		
Inspiration	Discouragement	(4)
Playful	***Serious***	(5)
Amusing	Boring	(3.83)
Satisfaction	Dissatisfaction	(3)
Extraordinary	***Average***	(5.67)
Surprising	***Predictable***	(6)
Useful	Purposeless	(2.33)
Professional	Amateurish	(3.67)

4. What kind of associations does prototype 2 evoke for you?

1 2 3 4 5 6 7		
Inspiration	Discouragement	(2)
Playful	Serious	(2)
Amusing	Boring	(1.18)
Satisfaction	Dissatisfaction	(3)
Extraordinary	Average	(2.83)
Surprising	Predictable	(2.33)
Useful	***Purposeless***	(4.16)
Professional	Amateurish	(3.16)

Test 2


Prototype 1


Prototype 2

Test 2

1. Which of the two prototypes is more appealing to you and why?

Prototype 2: Makes me the most curious, has depth and appeared interesting. Protype 1 is already clear what it is: stencil.
Prototype 2: Shape is more special, p1 is more valentine's day.
Prototype 1: More applicable, has more details.
Prototype 2: Very surprising, the realism of the rose is working better, since it is harder to recognize from the beginning.
Prototype 1: More clearly a rose.
Prototype 1: I don't know what prototype 2 is..

2. What kind of associations do you have with both prototypes?

Prototype 1: Rose.
Prototype 1: Romantic, the image is already visible: predictable.
Prototype 1: Tattoo.
Prototype 1: Coloring picture.
Prototype 1: Rose.
Prototype 1: Rose.
Prototype 2: Tornado, tunnel, Cave, Pastry (food).
Prototype 2: Mysterious.
Prototype 2: Paint strokes.
Prototype 2: Painting.
Prototype 2: Bird eye, hole.
Prototype 2: Face of a bear.

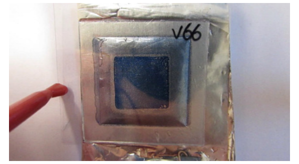
3. What kind of associations does prototype 1 evoke for you?

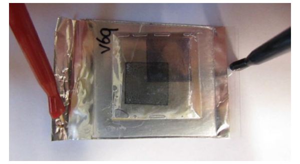
1 2 3 4 5 6 7		
Inspiration	Discouragement	(3.83)
Playful	Serious	(2.67)
Amusing	Boring	(2.83)
Satisfaction	Dissatisfaction	(3)
Extraordinary	***Average***	(4.16)
Surprising	***Predictable***	(5.16)
Useful	***Purposeless***	(4.33)
Professional	Amateurish	(3.67)

4. What kind of associations does prototype 2 evoke for you?

1 2 3 4 5 6 7		
Inspiration	Discouragement	(3.16)
Playful	Serious	(3.67)
Amusing	Boring	(3.33)
Satisfaction	Dissatisfaction	(3.16)
Extraordinary	Average	(2.33)
Surprising	Predictable	(2.83)
Useful	***Purposeless***	(4.67)
Professional	Amateurish	(3.16)

Test 3


Prototype 1


Prototype 2

Test 3

1. Which of the two prototypes is more appealing to you and why?

Prototype 1: Since it moved more smooth. Really good color vs.. transparency. Big contrast. The material behind it made the color disappear completely.
Prototype 1: It moves faster
Prototype 2: It has a more complex shape and overlap.
Prototype 2: Clear concept, is more satisfying in this (simple) design.
Prototype 2: More playful, more happening, overlap.
Prototype X: No preference.

2. What kind of associations do you have with both prototypes?

Prototype 1: Space, screen, solar panels.
Prototype 1: On/off phase.
Prototype 1: Proto 1.2.
Prototype 1: Negative of a film.
Prototype 1: Clouds in the air.
Prototype 1: Flash of lightning.
Prototype 2: Color mixing tests, games that overlap two colors.
Prototype 2: Mysterious, slow, have to look at it.
Prototype 2: Mondriaan.
Prototype 2: Covering text.
Prototype 2: None.
Prototype 2: 4 squares.

3. What kind of associations does prototype 1 evoke for you?

1 2 3 4 5 6 7		
Inspiration	Discouragement	(4)
Playful	***Serious***	(4.5)
Amusing	Boring	(4)
Satisfaction	Dissatisfaction	(3.5)
Extraordinary	Average	(4)
Surprising	Predictable	(4)
Useful	Purposeless	(3)
Professional	Amateurish	(3.33)

4. What kind of associations does prototype 2 evoke for you?

	1 2 3 4 5 6 7		
Inspiration		Discouragement	(3.16)
Playful		Serious	(3.67)
Amusing		Boring	(3.16)
Satisfaction		Dissatisfaction	(3.16)
Extraordinary		Average	(3.16)
Surprising		Predictable	(3.33)
Useful		Purposeless	(3.67)
Professional		Amateurish	(3)

Test 4.1

Test 4.1

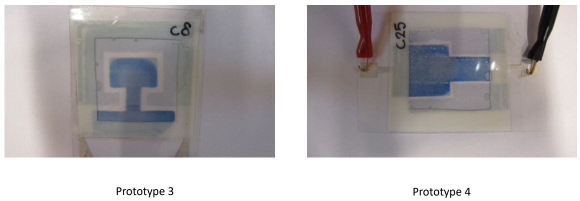
1. Which of the two prototypes is more appealing to you and why?

Prototype 1: Didn't go on a continuous speed, less perfect.
Prototype 2: Has more a story.
Prototype 2: The change is nicer.
Prototype 1: Shape is coming more to the front, through the strange loading, it created tension.
Prototype 1: More smooth.
Prototype 2: Shape.

2.. What kind of associations do you have with both prototypes?

Prototype 1: Broken, silhouette, flow, sweep.
Prototype 1: Hourglass, sunset, folded leaf, antipoles.
Prototype 1: Contrast, picture, magazine.
Prototype 1: Hourglass
Prototype 1: Water flow, clouds moving.
Prototype 1: None.
Prototype 2: Lens, contracting.
Prototype 2: Game, slide, zigzag, mountain.
Prototype 2: logo of the municipality of Utrecht.
Prototype 2: UNO card (game).
Prototype 2: None.
Prototype 2: Sunset.

Test 4.2



Test 4.2

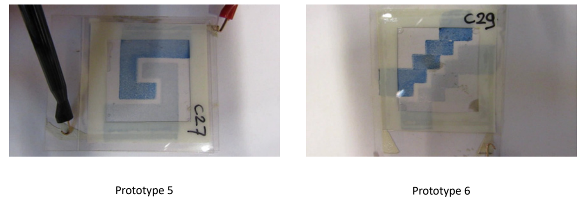
1. Which of the two prototypes is more appealing to you and why?

Prototype 3: Nice constant distance between the two parts, p2 feels like it has to be the same, but went wrong.
Prototype 3: Looks like an infographic.
Prototype 3: More movement.
Prototype 3: The shape is more appealing.
Prototype 4: Clearly an association with it. It's a swimming pool filling/emptying. P3 has to much white in-between.
Prototype X: No preference.

2.. What kind of associations do you have with both prototypes?

Prototype 3: Portrait: person/air. Focusing.
Prototype 3: Tree, house, heating system, Co2 insertion.
Prototype 3: Hourglass.
Prototype 3: Intersection: roller-bearing, Connectix.
Prototype 3: None.
Prototype 3: Person.
Prototype 4: Pool that's filling up. Pier with water.
Prototype 4: Building plan of a house, loss of heat.
Prototype 4: cross section of a nut.
Prototype 4: Intersection: axis of a jet engine.
Prototype 4: Pool that's emptying/filling.
Prototype 4: None.

Test 4.3



Test 4.3

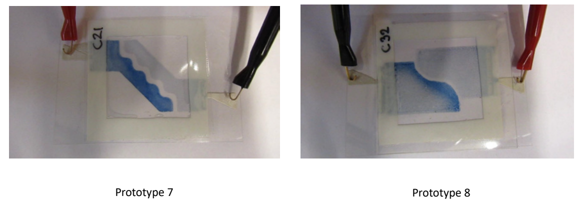
1. Which of the two prototypes is more appealing to you and why?

Prototype 6: It has coherence between the two shapes.
Prototype 6: The shape is filled more nice than the outer shape.
Prototype 6: The change is nice.
Prototype 6: The change is nicer/symmetrical.
Prototype 5: Two pieces of a puzzle.
Prototype X: No preference.

2.. What kind of associations do you have with both prototypes?

Prototype 5: Two arms, hook, construction.
Prototype 5: Connection, Greek, 2 hands in each other.
Prototype 5: Pattern, wall.
Prototype 5: Platform game.
Prototype 5: Pieces of a puzzle.
Prototype 5: None.
Prototype 6: Staircase, collision, chain reaction.
Prototype 6: Staircase, pattern for clothing, climb higher.
Prototype 6: Reflector, crossing gates (slagboom).
Prototype 6: Staircase of Escher.
Prototype 6: Staircase.
Prototype 6: Mirrored staircase.

Test 4.4



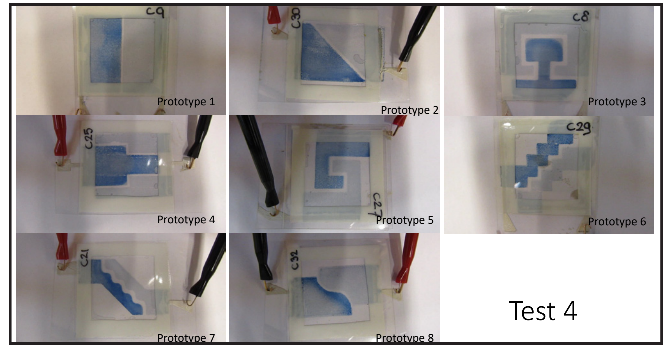
Test 4.4

1. Which of the two prototypes is more appealing to you and why?

Prototype 7: There is more going on, more places, p8 has more overview, so less interesting.
Prototype 7: Feels more symbolic, nice location, hands over the color to the other symbol.
Prototype 8: Nicer shape.
Prototype 8: The change is more nice, the shape is satisfying.
Prototype 7: More slim of shape. Coloring is more equal.
Prototype 7: More gracious.

2.. What kind of associations do you have with both prototypes?

Prototype 7: Flow of water, bathtub filling, waves, key.
Prototype 7: Organic, animal/beasty, 2 reaching arms.
Prototype 7: Escalator.
Prototype 7: Key.
Prototype 7: Staircase, razor-blade.
Prototype 7: Slat (aftimmer latje), ceiling molding.
Prototype 8: sea/coast.
Prototype 8: Sideview of the coast with respect to the air.
Prototype 8: Sea.
Prototype 8: Marble track (knikkerbaan).
Prototype 8: Shoes, clubfoot.
Prototype 8: None.



Test 4

Test 4_General

1. Which of all the prototypes of test 4 is the most appealing to you and why?

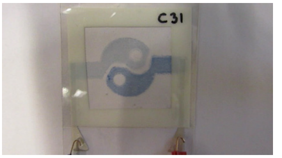
Prototype 6: clear/simple design. Lots of things happening. The coloring is surprising, not a staircase. Not predictable. Works together, looks like there handing something to each other.
Prototype 6: The color flow is nicely done from the points, a lot of points.
Prototype 3: You see the insertion of the color clearly.
Prototype 6: Nice how the points first color, he color change is nicely done.
Prototype 3: Illustration looks like a mechanism. The change of color is nice.
Prototype 5: Pieces of a puzzle.
Prototype 7: More graceful shape, graceful color change.

2. What kind of associations do all these prototypes evoke for you?

	1 2 3 4 5 6 7		
Inspiration		Discouragement	(2.16)
Playful		Serious	(2.16)
Amusing		Boring	(2.33)
Satisfaction		Dissatisfaction	(2.83)
Extraordinary		Average	(2.83)
Surprising		Predictable	(3.33)
Useful		Purposeless	(4)
Professional		Amateurish	(3.16)

Test 5

Prototype 1



Prototype 2

Test 5

1. Which of the two prototypes is more appealing to you and why?

Prototype 1: Clear design with sharp contrast and loose.
Prototype 1: I love Yin Yang.
Prototype 1: It's not linked to the sides: free/loose shape.
Prototype 2: Since prototype 1 is too recognizable/ cliché. P2 is adding extra dimension. It seems to be two hands holding each other. The color change fits to the composition.
Prototype 1: More graceful, touch each other. P2 has white in-between, weird square shapes connected to the side.
Prototype 1: More graceful.

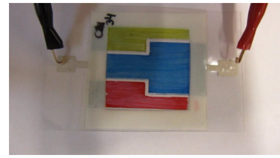
2. What kind of associations do you have with both prototypes?

Prototype 1: Yin and Yang!
Prototype 1: Fish = equality, Yin and Yang.
Prototype 1: Yin Yang.
Prototype 1: Yin Yang. Good/Evil. Classic cliché.
Prototype 1: Yin Yang.
Prototype 1: Yin Yang.
Prototype 2: Disabled Yin and Yang.
Prototype 2: Hands with a tennisball = change. The tennis ball is symbol for the exchange.
Prototype 2: Pokémon ball, hands.
Prototype 2: Hands, hug.
Prototype 2: Gloves, mittens.
Prototype 2: Earth-worm, two heads.

Test 6

Vorm 1

Vorm 2



Test 6

1. What colors are visible here (from top to bottom)?

Color 1: yellow/green, green, apple green, yellow
Color 2: blue, blue, blue, blue
Color 3: bright red, red, pink/red, red

2. What colors are visible here (from top to bottom)?

Color 1: green, mustard green, pine-tree green, green
Color 2: light blue, bright blue, light blue, cyan
Color 3: dark red with a hint of blue, Bordeaux red, fuchsia, little Bordeaux

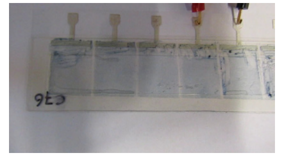
3. What kind of associations do you have with this prototype?

Focus, the blue is brightened.
Flag, natural colors, shadow on the nature outside, autumn.
Christmas, candy.
Toys/LEGO bricks, change is mood, blocks, hell/heaven/ earth.
Pool/grass/tiled floor.

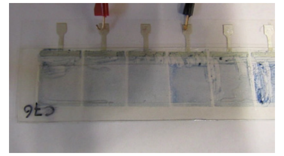
4. What kind of associations does prototype 1 evoke for you?

	1 2 3 4 5 6 7		
Inspiration		Discouragement	(3)
Playful		Serious	(2.33)
Amusing		Boring	(2.83)
Satisfaction		Dissatisfaction	(3.83)
Extraordinary		Average	(2.33)
Surprising		Predictable	(2.16)
Useful		Purposeless	(3.83)
Professional		Amateurish	(3.33)

Test 7



Prototype 1.1



Prototype 1.2

Test 7

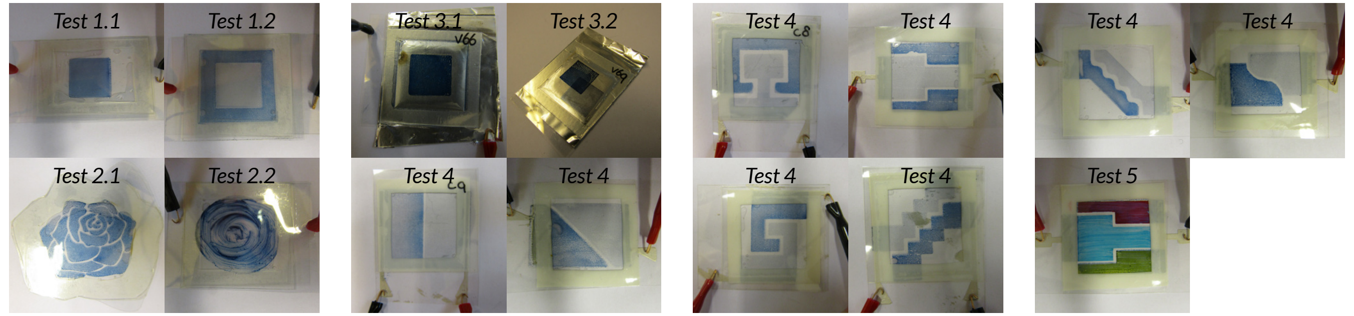
1. Which of the two shapes is more appealing to you and why?

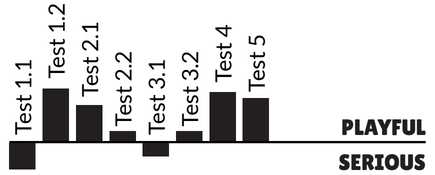
Shape 2: I don't get what happens.
Shape 1: I like predictable growth.
Shape 1: More and more blue (logical)
Shape 1: More predictable, works good with this simple shape. S2 was more on-clear what was going to happen.
Shape 1: More smooth coloring.
Shape 1: Logics: next to each other.

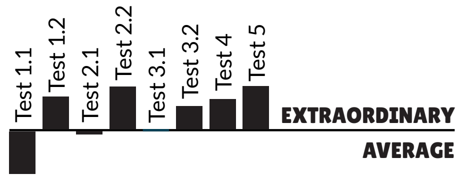
2. What kind of associations do you have with both shapes?

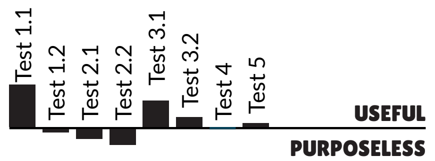
Shape 1: Xylophone, piano, volume bar, battery
Shape 1: Grabbing more and more, growth, loading bar, battery
Shape 1: Battery indicator.
Shape 1: Loading.
Shape 1: Bags of water filling?
Shape 1: None.
Shape 2: xylophone, piano, dog sleeping game: you're doing something here and something changes over there.
Shape 2: Randomness, point system, loose parties.
Shape 2: Game: guess which is changing.
Shape 2: Aquarelle paint, ink, overhead projector water show.
Shape 2: None.
Shape 2: Clouds.

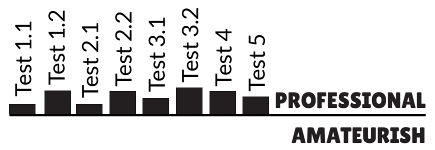
K USER RESEARCH 1: CONCLUSION AND ANALOGIES

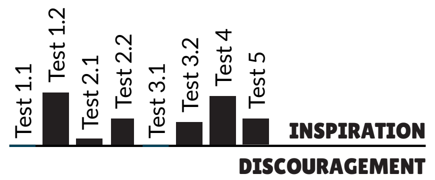


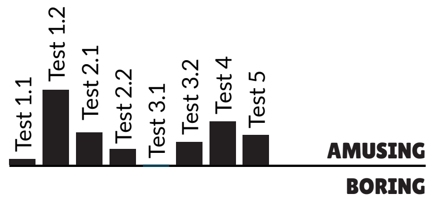


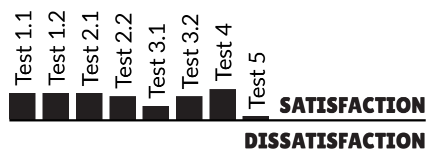


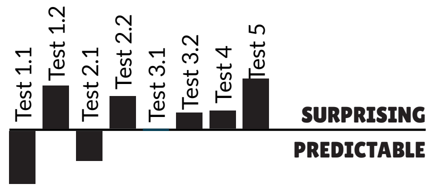












USER TEST ANALOGIES NOUN

Pastry (food)
Candy
Reflector
Space-suit
Pool/Grass/Tiled floor
Flag
Logo of the municipality of Utrecht
Dressing room
Building plan of a house
Ceiling molding (plafond lijst)
House

HEATING SYSTEM

Solar panels
Window
Opening
Zigzag
4 squares
Slide
Key
Escalator
Wall
Blinded windows

STAIRCASE

MIRRORED STAIRCASE

The news of the old days

NEGATIVE OF A FILM

NEXT IMAGE OF A VIDEO

Lens
Screen
Battery
Good/Bad
Anti-poles
Cliché
Cross section of a nut
Slat (aftimmer latje)
Intersection: roller-bearing
Intersection: axis of a jet engine
Hook
Construction
Crossing gates (slagbomen)
Tunnel
Cave
Mountain
Dog sleeping game

GAME

Games that overlap two colors
UNO card (game)
Connectix
Pokémon ball
LEGO
Pieces of a puzzle
Blocks
Ink
Picture
Aquarelle paint
Painting
Hands
Two hands holding each other
Two arms
Hands with a tennisball
Two reaching arms
Two heads
Clouds
Sea
Pier with water
Sea and cost
Folded leaf
Hole
Leaf
Tree
Shoes
Clubfeet
Portrait
Coloring picture

PIET MONDRIAAN

STAIRS: ESCHER

Person
Silhouette
Magazine
Yin Yang
Disabled Yin Yang

CONTRAST

Pattern
Tattoo
Rose
Earth-worm
Clouds in the sky
Christmas
Animal/beasty
Fish
Eye of a bird

X-RAY

Pattern for clothing
Mittens
Gloves
Autumn
Face of a bear
Piano
Xylophone

Point system
Loading bar
Battery indicator
Fade out (of an old tv screen)
VOLUME BAR
On/Off phase

Tornado
Mysterious
Grabbing more and more
Hug
Climb higher
Connection

CHAIN REACTION

FOCUSING (SCHERPSTELLEN)
Playful
Contracting (samentrekken)
Growth
Collision

USER TEST ANALOGIES MOVEMENT

Sweep
Paint strokes
Color mixing tests
PLATFORM GAME
Science reaction
Marble track (knikkerbaan)
Covering text
HOURGLASS

Flow
Pool that is filling up
WATER FLOWING
Bathtub filling
Sunset
Waves
Clouds moving.
CO2 insertion
Heat loss
Flash of lightning
Bags of sand filling

Crowd management

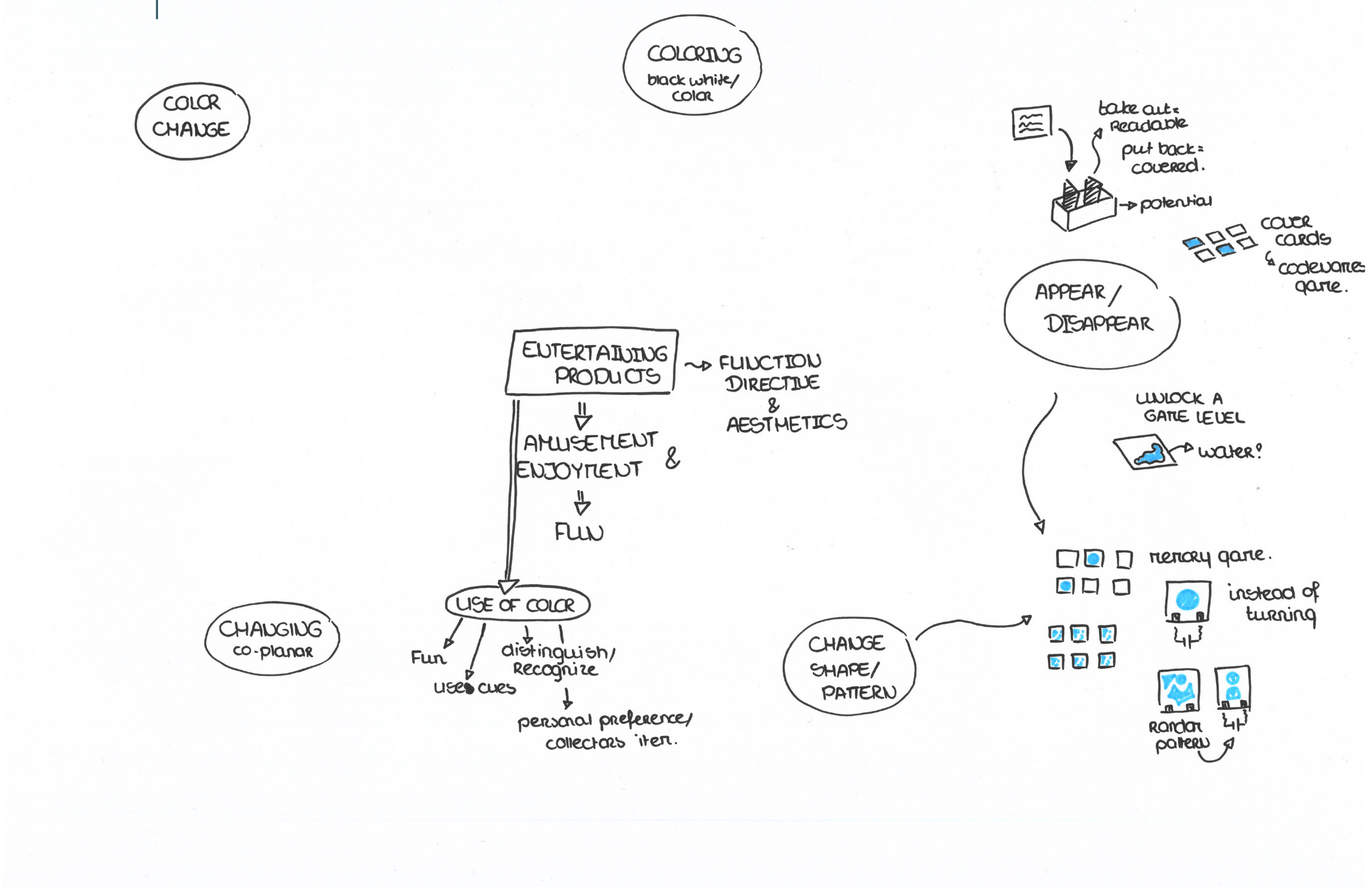
RANDOMNESS

This page is intentionally left blank

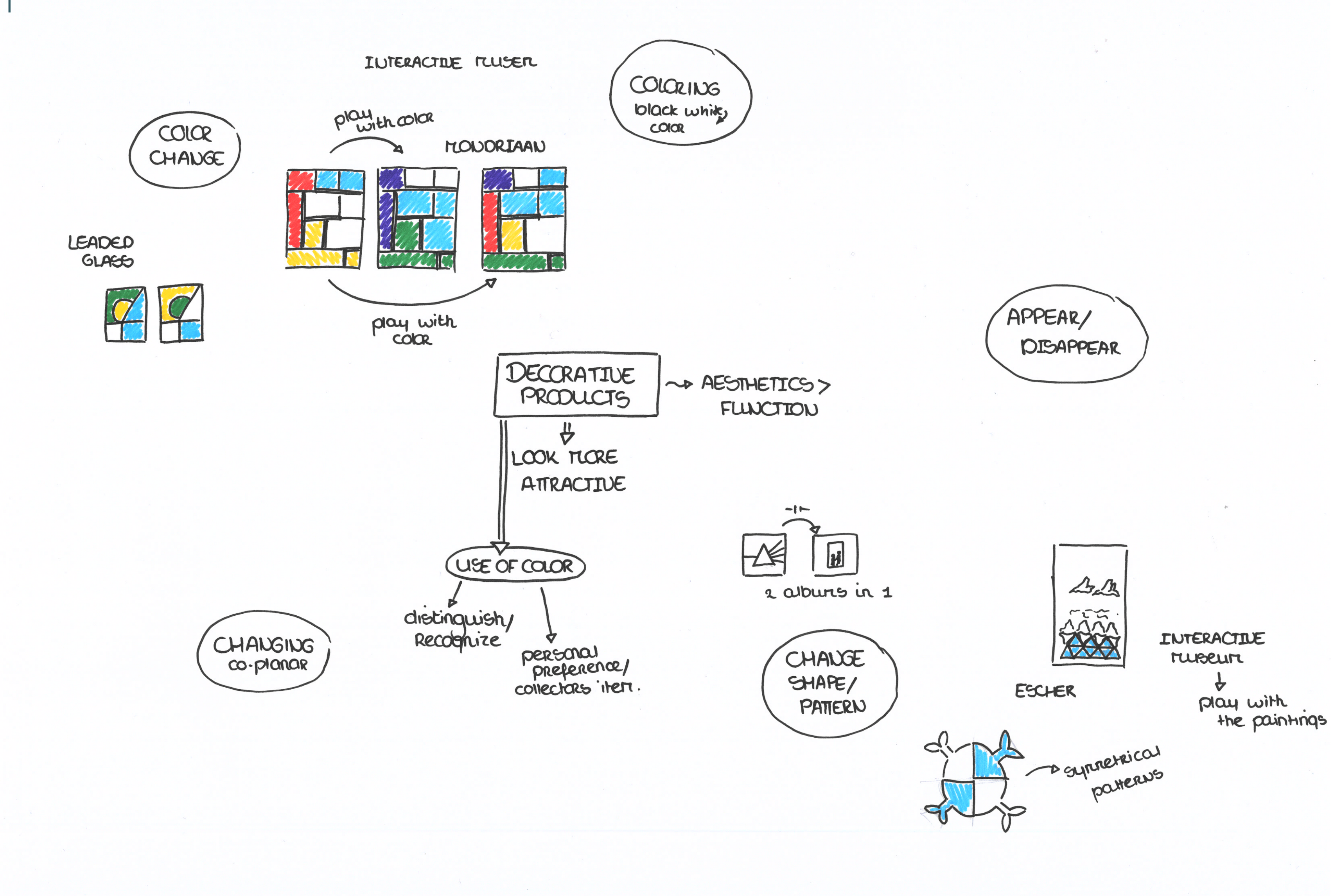
L INSPIRATIONAL MIND-MAPS

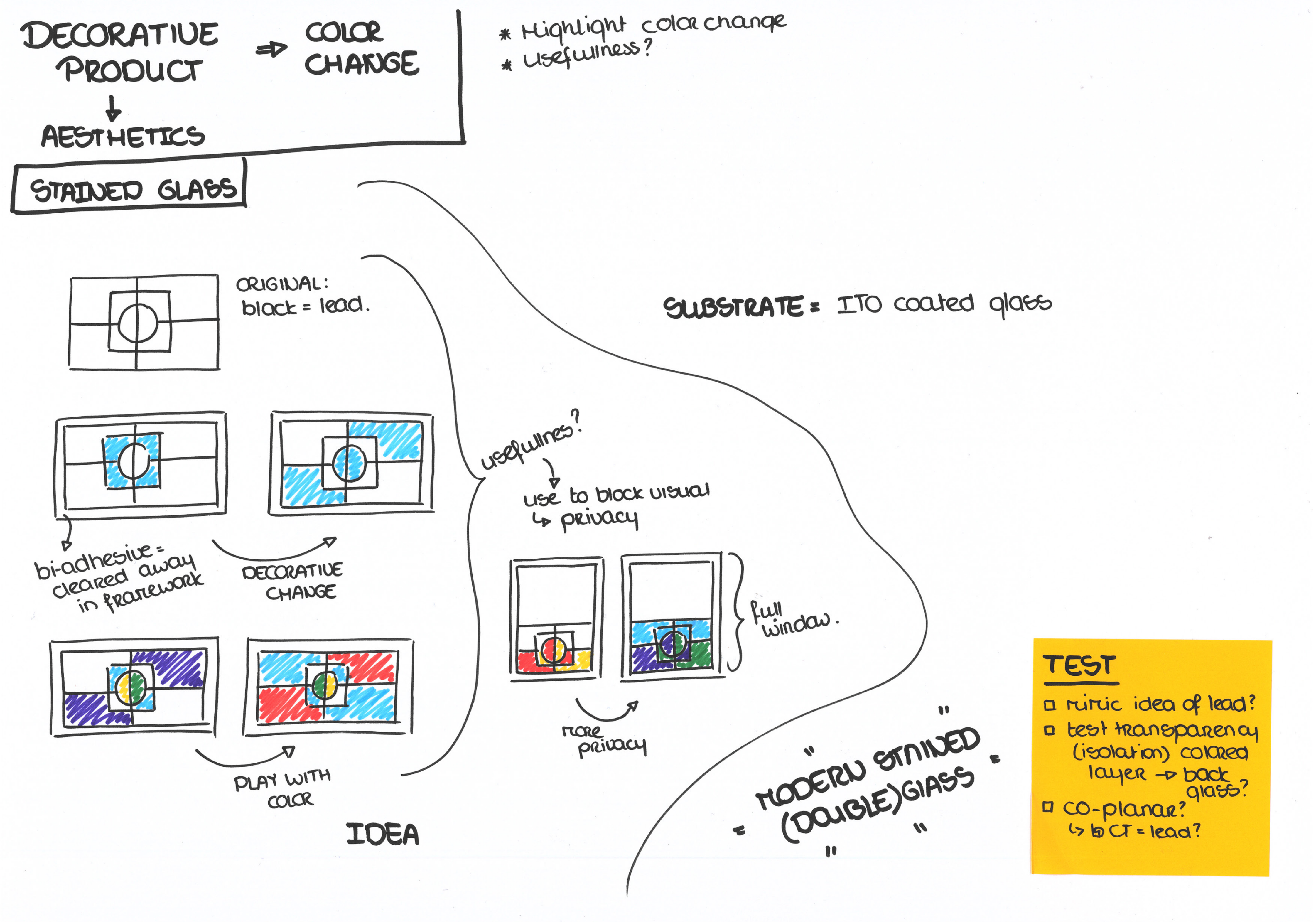
This page is intentionally left blank

M IDEA GENERATION: ENTERTAINING PRODUCTS

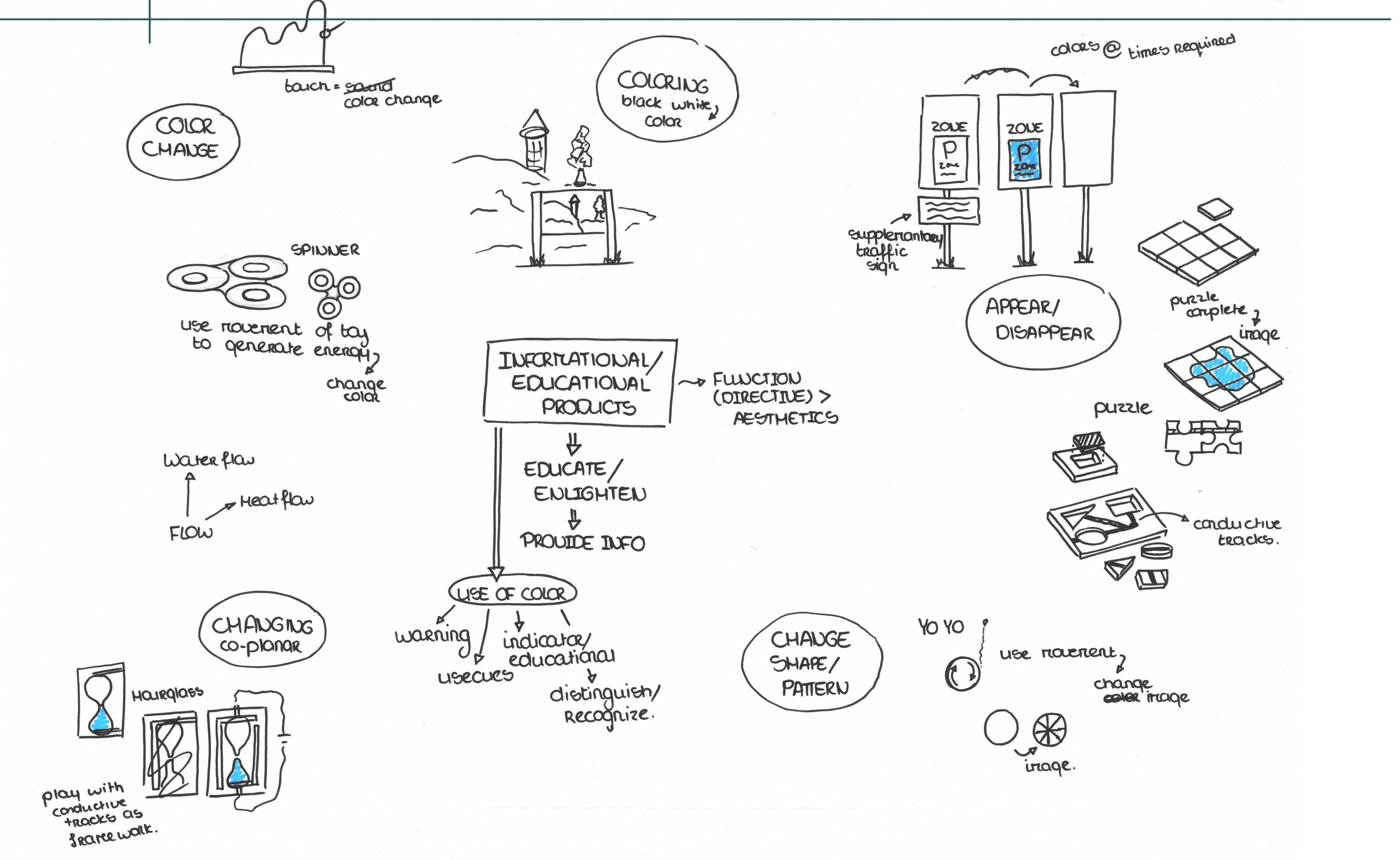


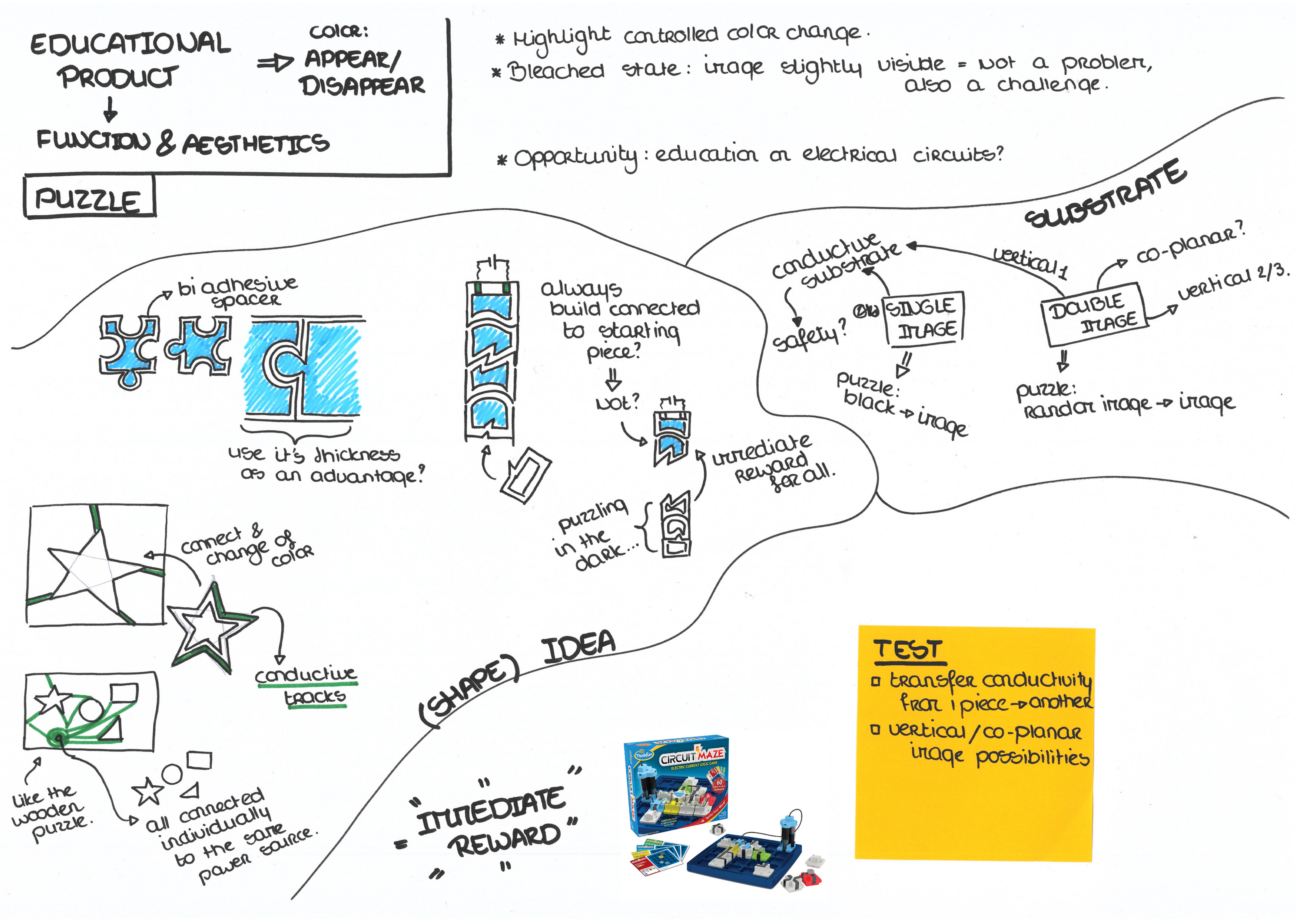
N IDEA GENERATION: DECORATIVE PRODUCTS





O IDEA GENERATION: EDUCATIONAL PRODUCTS





P INSPIRATIONAL MIND-MAP: PUZZLES

Q COST CALCULATION: 'THE PUZZLE OF ELECTROCHROMISM

MATERIAL SPECIFICATIONS	MATERIAL SPECIFICATIONS: PURCHASE	PRICE [€]	MATERIAL SPECIFICATIONS: 'THE PUZZLE OF ELECTROCHROMISM'	PRICE [€]
INDIVIDUAL PUZZLE PIECES				
Coperfoil tape	5mm x 25m	€11,95	105mm	€0,19
Magnets nickel-plated N35	5mm x 3mm (price per piece)	€0,22	8 pieces	€1,76
Plexiglass	500mm x 600mm x 2mm = 300.000 mm^2	€5,98	3600mm x 4 pieces = 14.400 mm^2	€0,30
ECD: puzzle piece #1	n/a	n/a	n/a	€2,67
ECD: puzzle piece #2	n/a	n/a	n/a	€2,86
ECD: puzzle piece #3	n/a	n/a	n/a	€2,94
ECD: puzzle piece #4	n/a	n/a	n/a	€1,74
FRAMEWORK				
Plexiglass	500mm x 600mm x 2mm = 300.000 mm^2	€5,98	41.800mm^2	€0,86
Magnets nickel-plated N52	5mm x 2mm (price per piece)	€0,34	8 pieces	€2,72
SunChemical Silver Paste: C2120918P1	50g	€203,00	0,5g (rough estimation)	€2,00
Battery holder: SMTU 2032-LF	Lithium CR2032 coin cells (price per piece)	€0,69	1 battery holder	€0,69
Lithium CR2032 coin cell battery	3V (price per piece)	€0,502	1 battery	€0,502
GLUE				
Circuitworks conductive epoxy: CW2400	7g	€77,04	0,2g (rough estimation)	€1,3
Loca TP-1000N UV glue	50g	€13,59	1g (rough estimation)	€0,27
			Total:	€20,80