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APPLICATION OF AXIOMATIC DESIGN FOR ENGINEERING PROBLEM SOLVING AND DESIGN USING MECHANISM-BASED SOLUTION DESIGN: PART 2

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ABSTRACT

This paper proposes a novel solution to a standing problem in LCD panels for TVs using Mechanism-based Solution Design (MSD). The research follows the three-step process of MSD. The first step was to define all issues in the process. In this step, the gap analysis of MSD revealed a "high current pinhole" problem in the external electrode fluorescent lamp (EEFL). The next step was to analyze the mechanism process, which revealed the core parameters and the failure mechanism of high current pinhole failures through a set up and test hypotheses. Finally, in the determining the solutions process, a novel solution was provided to EEFL back light unit (BLU) pinhole failure by Axiomatic Design (AD), which led to the validation of the design by an accelerated life test. In addition, this paper proposes a new approach for engineering problem-solving and design in order to more easily access the solutions in AD. The author hopes that more engineers will be able to solve engineering problems better using AD.

Keywords: Axiomatic Design, Mechanism-based Solution Design, MSD, EEFL BLU for LCD, pinhole.

1 INTRODUCTION

Part 1 of this work introduced the "current states" site failure mechanism-based effects analysis, conceptual design in the "desired results" site and how it was adaptable to every domain in AD. This helps to define the issues clearly for newly suggested problem definitions and functional requirements evaluation.

As an example, the actual problem of EEFL BLUs for LCD TVs was introduced. This has been a longstanding problem in the LCD BLU market. In part 1, we analyzed current states and produced a conceptual design using AD. Part 2 introduces the core MSD processes such as defining the issues, examining the failure/functional mechanism by hypothesis, refining the desired solution, optimizing solutions and reliability assessment. The Mechanism-based Solution Design (MSD) process is the first contribution in this paper for a clear way to setup an efficient decision making process in Axiomatic Design. Therefore many design engineers can effectively access the solutions of each domain in Axiomatic Design.

2 REVIEW OF PRIOR PROCESSES

MSD proposes a three step process for analyzing the mechanism of issues and the solution design process with systematic thinking.

- Step 1: Define the issues.
- Step 2: Analyze the functional/failure mechanism.
- Step 3: Determine the design solution

Defining the issues of the target system focuses on "what are the problems to be solved". In part 1, "issues" are defined as the set of defined problems which make up the gap between the "current statuses" and "desired results" viz. the challenges. The same process of defining the issues can be applied to all of the domains of AD, as follows in these three phases:

- Phase 1: Identify the current states.
- Phase 2: Develop the desired results.
- Phase 3: Define the issues.

In part 1, as an example, the actual problem of EEFL BLUs for LCD TVs was introduced. We have developed the desired results as a conceptual design, which is as follows: the functional requirements (FRs) are defined to satisfy the original perceived needs. The appropriate set of design parameters (DPs) to satisfy the FRs must then be defined via a physical entity. The proposed solution is then analyzed using design axioms.

3 MECHANISM-BASED SOLUTION DESIGN

3.1 DEFINE THE ISSUES

In MSD, issues (ISs) are defined to narrow the scope of analysis for an efficient decision-making process. The definition of an "issue" is the gap between the "Current States" (CSs) and "Desired Results" (DRs) of each domain so that we can define "What are the problems to be solved". The defined issues are obvious problems to be solved. The resolution of these issues is the goal of the design in each domain. The selection of issues is validated based on the gap between the functional failure models (FMs) and the desired results in each domain, and between the defined issues between the various domains.

Table 1 lists the current states, defined issues and desired results in each domain. CMSs, CFRs, CDPs and CPVs are the current marketing strategies, current functional requirements, current design parameters, and current process variables.

Similarly, IMSs, IFRs, IDPs, and IPVs are the set of defined issues in each domain, and MSs, FRs, DPs, and PVs are the desired marketing strategies, functional requirements, design parameters and process variables.

Table 1. Defining the issues of the target system.

Current States (CSs)	Defined Issues (ISs)	Desired Results (DRs)
CMSs	IMSs	MSs
CFRs	IFRs	FRs
CDPs	IDPs	DPs
CPVs	IPVs	PVs

The relationship (the set of issues IS) between a set of design results (DR) & the corresponding set of current state (CS) is given by:

$$\{IS\} = \{DR\} - \{CS\} \quad (1)$$

Therefore:

$$\{IMS\} = \{MS\} - \{CMS\} \quad (2)$$
$$\{IFR\} = \{FR\} - \{CFR\} \quad (3)$$
$$\{IDP\} = \{DP\} - \{CDP\} \quad (4)$$
$$\{IPV\} = \{PV\} - \{CPV\} \quad (5)$$

The priority of defined issues needs to determined in each domain. In the EEFL BLU for LCD TV example, the defined issues are as follows:

IMS1 Increase the profit.
- **IMS11** Increase our order by supplying cheaper and better luminance BLU for customer.
- **IMS13** Customers develop LED BLU with H-Company.

IFR1 Provides better value and increase our profit.
- **IFR11** Resolve pinhole failure at 12mA operation and assure the reliability.
  - **IFR111** Reduce current density
  - **IFR112** Increase lamp diameter.
  - **IFR113** Reduce damage of high-voltage discharge or surge
  - **IFR114** Change external electrode material and method
- **IFR13** Develop LED BLU with MSD.

IC1 Reduce cost 30%.
IC2 Save 30% power consumption.
IC3 Achieves the 60000h reliability of EEFL BLU at 12mA operation.
IC4 Achieves the lamp colour coordinates changed by aging degradation less than 10% from new one.
IC5 Achieves quality variance less than 5% of the luminance dispersion of each lamp.

where an **IC** is an issue constraint.

IDP1 Pinhole free high current operation EEFL lamp.
- **IDP11** Analyzing pinhole mechanism.
  - **IDP111** Current density
  - **IDP112** Lamp diameter.
  - **IDP113** High-voltage discharge or surge
  - **IDP114** Different electrode

IPV1 Pinhole free high current operation EEFL lamp.
- **IPV1** Accuracy of test data and ability of analyzing
  - **IPV111** Accuracy of test
  - **IPV112** Accuracy of test
  - **IPV113** Test method
  - **IPV114** Developments of new electrode

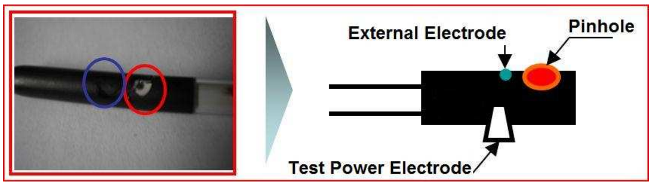

Figure 1. The phenomenon of pinhole failure in EEFL.

By defining issues, we narrow the scope of our analysis to pinhole failure mechanism analysis (figure 1). Therefore, we can focus on analyze pinhole failure mechanism and design solutions in following steps.

3.2 DEFINE THE MECHANISMS MODEL OF THE ISSUES

To recognize "what I don't know" is the essence of problem solving. In this step, we determine "Where is the mechanism model" (figure 2).

- Phase 1: Check the hypothesis and parameters into the issues.
- Phase 2: Check the hypothesis and parameters into the issues.
- Phase 3: Define the mechanism model.

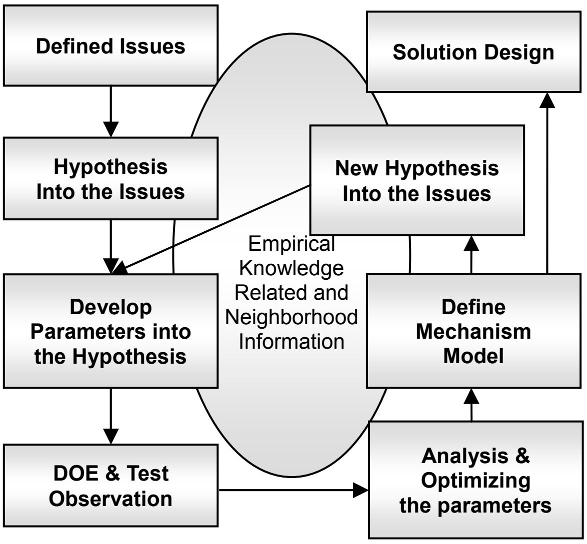

Figure 2. Analysis the mechanisms of the issues.

3.2.1 CHECK THE CURRENT HYPOTHESIS AND PARAMETERS INTO THE ISSUES

This phase checks the hypothesis or specifications into the issues and the basis of hypothesis and reviews the hidden parameters with a 'zigzagging' process. The scope of hypothesis in this phase includes specification, tolerance, theoretical or experimental claims and environmental conditions. The classification method of hypothesis is introduced in table 2. One caveat here is that the hypothesis needs to keep in mind is that it should be answering 'Yes' or 'No' questions.

Table 2. Current hypothesis, parameters and basis.

Hypothesis into issues	Parameters in hypothesis	Basis of hypothesis
1) Low current density increases pinhole failure current.	-Area of external electrode	Increase the area of the electrode then current density is reduced. Thus stress in the glass will be reduced.
2) Enlarging the lamp diameter increases the occurrence of pinhole failure	-Diameter of lamp -Area of electrode -Thermal effects of plasma	Enlarge the lamp diameter with the same electrode then thermal effects of the plasma will be reduced.
3) High-voltage discharge or surge is the cause of pinhole failure. [Matsushita, 2005]	-Power electrode position -Pinhole position -Voltage	Supply high voltage to the electrode positioned on opposite side of glass pinhole failure occur by surge
4) Pinhole failure current depends on electrode resistance	-Resistance of external electrode	The pinhole test results depend on test carbon paste vs. metal can & soldering viz. pinhole current depends on electrode resistance.
5) Pinhole failure current depends on electrode material and shape.	-Heat transfer of electrode material	The pinhole test results depend on test jig vs. clip jig, and carbon paste vs. metal can & soldering viz. pinhole current depends on electrode shape and material.
6) Pinhole failure position depends on test electrode position.	-Test electrode contact position -Lamp inside convection	Pinhole failure position has the regularity which depends on test electrode position.

The development of influence parameters in issues asks, "Where is the problem". The purpose of this process is to determine "vital Xs". The scope of the parameters includes not only parts, but also functional/environmental specifications of design.

3.2.2 VERIFY THE HYPOTHESIS AND ANALYZE THE PARAMETERS

Until the hypotheses are explicitly expressed, the verification of hypothesis is performed through qualitative and quantitative analysis of the facts. Therefore, we need designs of experiments (DOE) and tests for the verification of hypotheses and measuring specifications with an out of the box way of thinking. In my experience, most problems can easily be solved through this phase before analysis of the hidden mechanism in the next phase.

Table 3 shows the verification method, parameters, and the results of hypothesis into issues.

Table 3. The hypothesis verification method, parameters, and the results.

Hypothesis verification methods	Parameters in verification	Verification Results	Yes/No
1) Increase the area of electrode and check the pinhole failure current without enlarging the lamp diameter.	-Length of external electrode -Length of electrode is limited by TV bezel width, as 25mm	Increase the length of electrode then pinhole occurrence current goes up to 13mA and the luminance of lamp is upgraded	Yes
2) Enlarge lamp diameter increase with same area of electrode then pinhole failure current increases. This test result is shown in figure 4.	-Diameter of lamp -Area of electrode -Thermal effects of plasma	Enlarge lamp diameter then pinhole current goes up to 13mA but the luminance of lamp is degraded.	Yes
3) High-voltage discharge or surge is cause of pinhole failure [Cho, 2004]. This test result is shown in figure. 4	-Power electrode position -Pinhole position -Voltage	Power supply test electrode positioning on upside down to lamp the pinhole failure position is same.	No

4) Change the electrode resistance then pinhole failure current is influenced by electrode material and method. This test result is shown in fig. 6	-Resistance of external electrode	The pinhole test results depend on lamp electrode material such as carbon paste vs. metal can & soldering viz. pinhole current depends on thermal conductivity. This test result is shown in fig. 6.	Yes or No
5) Pinhole failure current depends on electrode material and shape. This test result is shown in fig. 5 and 6	-Heat transfer of electrode material -Different kinds of test electrode	The pinhole test results depend on test jig vs. clip jig, and carbon paste vs. metal can & soldering viz. pinhole current depends on electrode shape and material.	Yes
6) Pinhole failure position depends on test electrode position. This test result is shown in fig. 4 [Cho, 2004]	-Test electrode contact position -Heat transfer of external electrode	Pinhole failure position has the regularity by the convection of lamp inside without other heat transfer but it depends on the condition of heat transfer. Shown in fig. 4, 7	Yes or No

The verification test bench consists of a DC power supply, an inverter, point contact power electrodes and a data acquisition system for precision testing, as shown in figure 3.

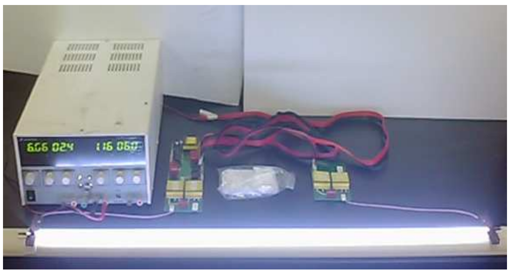

Figure 3. Hypothesis verification test bench.

For the fidelity of hypothesis verification tests, samples are made by the same condition as the factory. The following verification results are tested by the samples.

Figure 4 shows various EEFL electrodes (left) and various power electrode contact positions which depend on the pinhole position characteristics (right). These test results show that we can conclude that pinhole failure is influenced by gravity and contact position which means that the convection and plasma discharge behaviour inside of the lamp are influence parameters.

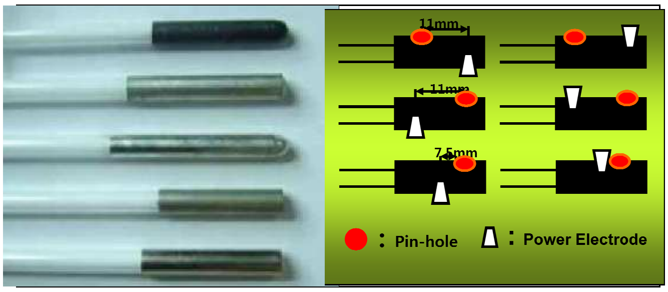

Figure 4. Various electrode of EEFL [Gill, 2005](left) and Power electrode position vs. pinhole position(right).

Clip type (left) for LCD TV BLUs vs. point contact type (right) test bench power supply electrodes are shown in fig. 5. The purpose of test bench power electrode is to test accuracy which prevents the influences of the heat transfer.

Figure 5. Clip type in LCD TV (left) and test bench (right) power electrode.

In figure 6, the left figure shows luminance dispersion reduced within 5% by the type of external electrode of lamp, which is can type vs. carbon paste type. The right figure shows the pinhole test results according to various types of power supply electrode and lamp external electrodes.

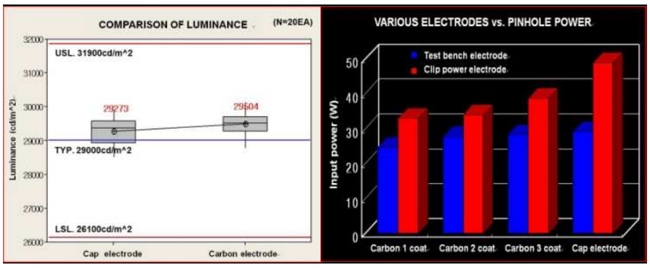

Figure 6 Various types of external electrodes and pinhole test results.

For in-depth analysis of parameters, the analysis of the hypothesis of the issues will gradually reveal the implied mechanisms in issues. If the empirical knowledge is lacking, optimization results are very important to understanding the relationship of the parameters. Therefore, designers should have the ability to observe test benches and analyze the parameters optimization results. Finally we derive inconsistencies in hypothesises which we need to analysis the mechanism. The definition of the inconsistency is the logical gap between the functional/physical phenomena and hypothesis in MSD.

3.2.3 DEFINE THE MECHANISM MODEL OF THE ISSUES

Defining the mechanism model refers to "Why the issues occur". This step reveals the actual functional/physical mechanisms which could not explain the occurrence of the issues. New hypothesises reset to express the prior issues/phenomenon and overcome the inconsistencies of the existing hypotheses. Here, the engineer's creativity and observation will be required to analyze the issues/phenomena.

Table 4. New hypothesis, parameters and basis.

New hypothesis into issues	Parameters in new hypothesis	Basis of new hypothesis
1) Pinhole failure current depends on heat transfer of the electrode thus improving heat transfer conditions and increasing the softening point of the glass is helpful.	-Heat sink -Heat transfer of electrode	Prior test fig. 4 shows convection. Figs. 5 and 6 show the conduction behaviour in EEFL pinhole test results. Radiation is also a considerable factor but fig. 6 shows that the effect is weak.
2) If we can make a transparent electrode, we can observe the pinhole failure situation.	-Making transparent electrode	Observe the behavior of the plasma inside the lamp and the progression of failure which helps to understand the pinhole phenomenon.
3) Heat will be brought 2000V 65kHz operating condition and lamp glass working as dielectric material, thus molten glass wall sucked lamp inside by vacuum	-Power loss characteristics of glass material -Frequency -Temperature -Softening point	High frequency heating phenomenon happens in most of the material that is depending on the characteristics of the material, frequency and current density

The determination of the mechanism is the process of the integration of facts which is acknowledged through the verification of new hypotheses. Table 5 shows the new hypothesis verification process.

Table 5. New hypothesis verification method, parameters, and the results.

New hypothesis verification methods	Parameters in verification	Verification Results	Yes/No
1) The "C" and "O" type heat transfer material (mud) coated at the electrode, Fig. 7 shows the behaviour of heat transfer by pinhole position	-Heat sink material (nonconductive) -Heat transfer difference	Pinhole test results of heat sink coated EEFL show conduction and convection is the 1st and the 2nd influenced parameter	Yes
2) If we can make a transparent electrode, we can observe the situation of pinhole failure.	-Making transparent electrode	Fig. 8 shows the behavior of lamp inside the pinhole failure This test was useful to understand the pinhole failure	Yes
3) Heat will be brought 2000V 65kHz operating condition and lamp glass working as dielectric material.	- The dissipation factor of glass material -Frequency -Voltage	High frequency heating revealed by study of dissipation factor This is power loss effect of high frequency operation.	Yes

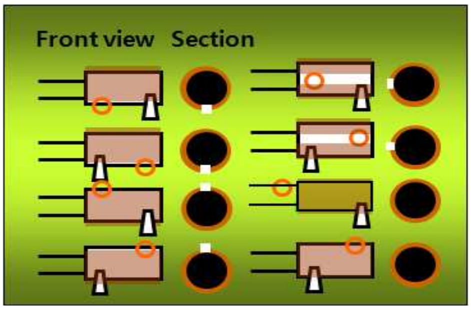

Figure 7. The test sample for "C" and "O" shape nonconductive heat transfer material (mud) coated at the outside of electrode.

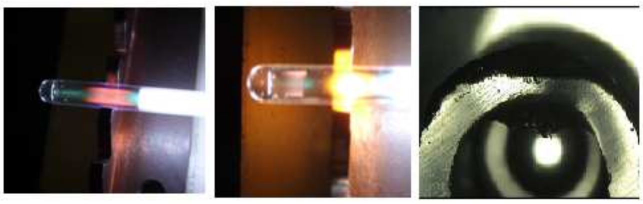

Figure 8. Behavior of the plasma inside the lamp (left) and the progression of pinhole failure (center). The sectional view of lamp shows internal state of pinhole failure (right).

The left photo in figure 8 shows the initial low-current state. The center photo shows the glass as it starts to boil before pinhole failure. The section view of lamp glass (right) shows the internal state of lamp pinhole failure. We can see the signs of glass boiling bubble pieces. Inside of the lamp is a vacuum condition. If the temperature softens the glass, the tube wall will gradually suck inside and burning will occur by high temperature plasma of glass tube center.

Glass heating turns out to be an important parameter. Electric power is dissipated in all dielectric materials, usually in the form of heat. The dissipation factor (DF) is a measure of loss-rate of AC power. The DF will vary depending on the dielectric material and the frequency of the electrical signals [Ramo *et al*, 1994]

We need to establish the theoretical background and the logical structure of the revealed mechanism of issues for new design. Therefore, this will help define "Why the critical issues occur", which will help in discovering the most efficient way to decide new design solutions.

Therefore, we define the pinhole failure mechanism in EEFL as "the phenomenon of lamp glass melted by heat". The defied mechanism of EEFL BLU is shown in table 6.

3.3 Determine the Design Solutions

We need to refine the FRs, DPs and PVs and also systematically check the mechanism matrix with the *Independent Axiom*. We must also analyze the mechanism matrix with the principles of Axiomatic Design [Suh, 1990] and optimize the production variables.

- Phase 1: Refine the desired results.
- Phase 2: Optimize the design solutions.
- Phase 3: New design validation.

3.3.1 Refine the Desired Results

Designers redefine the solutions such as MSs, FRs, DPs and PVs more ideally; nevertheless, it will eventually satisfy customers' demands. Making an optimal design matrix is essential for using the defined mechanism model. These concepts are somewhat different between AD and MSD because the desired results or mechanisms defined at the ideal place instead of a "zigzag" approach will help find more creative DPs for "good design", which will increase the chance to surprise ourselves with the creativity of design results. Designers can come up with ideas of FR, DPs, and PVs by the recommended process. The recommended ideating actions are the creation of the desired results and the review of the mechanism models after looking for variable parameters, which professional engineers expresses into 9 kinds of references as follows: removing, rearrange, replace, split or combine, adapt (include the meaning), modify (zooming), change of use (function, environment), use the idle resources and reference new technology or patents

The determined design solutions should be checking the logical compatibility based on the concept of mechanism model which has been worked on the previous step.

We should be refine the FRs, DPs and PVs based on the revealed mechanism.

Table 6. The EEFL failure mechanism analysis results.

Phenomena/ Definitions	Effects	Parameters
Pinhole failure: Lamp glass melted by heat	Glass heat	Dissipation factor (DF) of lamp glass
	Glass sucked inside of lamp by vacuum, viz. strength	Softening point of lamp glass
	Reduce glass temperature by heat transfer	Heat sinking of electrode
	Reduce the influence of convection	Diameter of lamp.
	Make heat source	Current density
	Glass sucked inside of lamp by vacuum, viz. force	Pressure difference
Colour coordinates change: Phosphors degradation by heat	Colour coordinates change and luminance degradation	Reliability of phosphors
Luminance dispersion of each lamp: Quality variance by production variables	Electric resistance dispersion of each lamp	Thermal contact resistance with external electrode and lamp glass
	Other effects	Other production variables

FR1 Provides better value to LCD TV and increase our profit.
- **FR11** Provide pinhole free BLU at 12mA operation and assure the reliability standard.
  - **FR111** Reduce the heat of lamp glass due to power loss
  - **FR112** Increase the heat resistance of the lamp glass
  - **FR113** Increase thermal conductivity from glass to electrode and heat sinking
  - **FR114** Be optimized the diameter of the lamp glass for reliability, luminance and cost.
  - **FR115** Increase the area of the external electrode.
- **FR12** Reduce the degradation of performance
  - **FR121** Reduce the change of colour coordinates.
  - **FR122** Reduce mercury turns to amalgam.
  - **FR123** Reduce the luminance dispersion of each lamp quality variance less than 5%.

DP1 Provides better value to LCD TV and increase our profit.
- **DP11** Provide pinhole free BLU at 12mA operation and assure the reliability standard.
  - **DP111** Dissipation factor (DF) reduced by half lamp glass
  - **DP112** Softening point from 360°C to 420°C increased lamp glass
  - **DP113** Thermal conductivity increased electrode
  - **DP114** Diameter optimized 3.4mm lamp.

DP115 Area of external electrode enlarges to 30mm

DP12 Reduce the degradation of performance

DP121 Improved quality phosphor.

DP122 Na on the inner surface of lamp glass is removed by acid wash.

DP123 Past/Solder electrode is applied to improve contact with the lamp glass and the electrode.

$$\begin{Bmatrix} FR111 \\ FR112 \\ FR113 \\ FR114 \\ FR115 \\ FR121 \\ FR122 \\ FR123 \end{Bmatrix} = \begin{bmatrix} X & & & & & & & \\ & X & & & & & & \\ & & X & & & & & \\ & & & X & & & & \\ & & & & X & & & \\ & & & & & X & & \\ & & & & & & X & \\ & & X & & & & & X \end{bmatrix} \begin{Bmatrix} DP111 \\ DP112 \\ DP113 \\ DP114 \\ DP115 \\ DP121 \\ DP122 \\ DP123 \end{Bmatrix} \quad (6)$$

We developed a new lamp glass with a dissipation factor that is half of the present alkaline glass and that increases the glass softening point from 360°C to 420°C. The results are shown in figure 14. We also achieved a pinhole failure current increase from 12mA to 16mA.

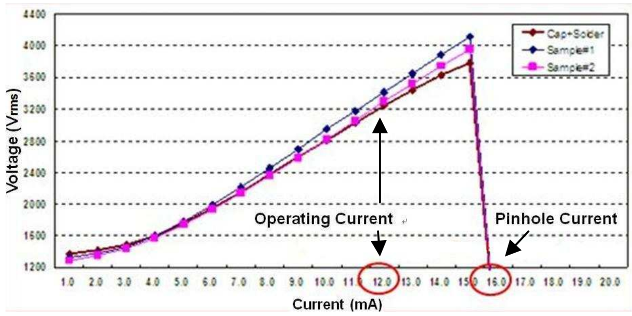

Figure 9. The pinhole test results of developed EEFL.

We need to check the fidelity of the design solution through constraint variables such as convenience, cost and reliability requirements.

IC1 Reduce cost 30% by reducing 8 lamps to drive the lamp 12mA.

IC2 Save 30% power consumption by reducing 8 lamps to drive the lamp 12mA.

IC3 Achieves the 60000h reliability of EEFL BLU in 12mA operating condition. Satisfactory running life test

IC4 Achieves the lamp colour coordinates changed by aging degradation less than 10% from new one. To include FR

IC5 Achieves quality variance less than 5% of the luminance dispersion of each lamp. To include FR

3.3.2 Optimize the Design Solutions

The design is prepared to market, design parameters from various alternatives ideas are made, and a check on the manufacturability of design ideas as production variables (PVs) vector settings based on ideal mechanism is also performed.

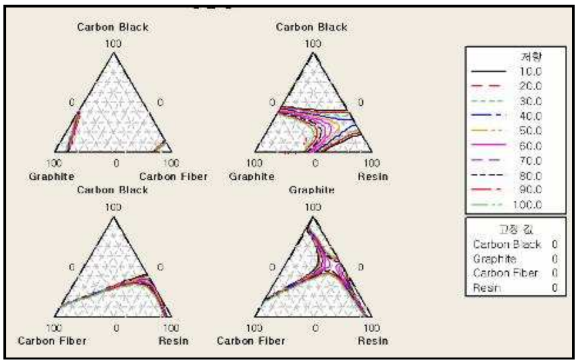

Figure 10. Optimization results of parameters.

The determinations of optimal DPs and PVs should be refined through qualitative evaluation to achieve a more creative "good design" with the design of experiments (DOE). The tests and analysis of various alternatives are performed for the optimization of the value of parameters until production variables achieve a "Robust Design" which is easy to manufacture.

Figure 11. The present EEFL vs. new developed EEFL.

3.3.3 New Design Validation

The new design validation test designed for examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. The evaluation should be performed to determine aspects of reliability, which identifies "What should be refined". The reliability assessment process forming the basis of MSD process follows figure 10. It consists of six key steps: [Evan, 2001].

- Technical assessments to characterize the materials and processes.
- Identification of potential failures (sites and mechanisms).
- Modeling the mechanisms under the acetated life cycle loads
- Test matrix development
- Execution of accelerated testing
- Detailed failure analysis.

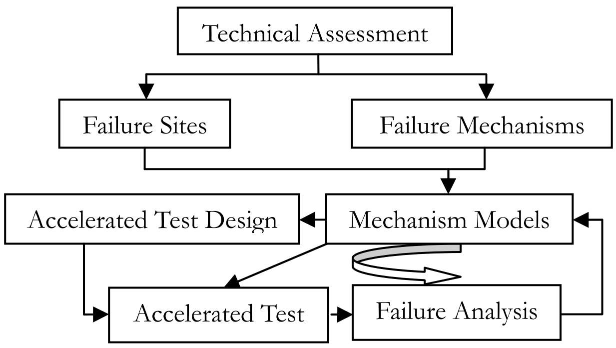

Figure 12. The reliability assessment process in MSD.

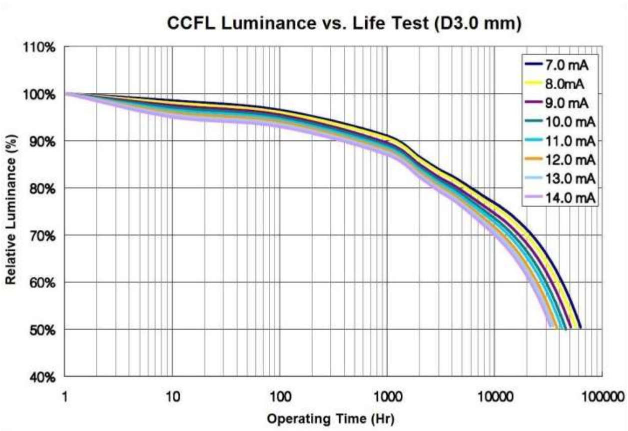

Figure 13. The life test result of conventional CCFL.

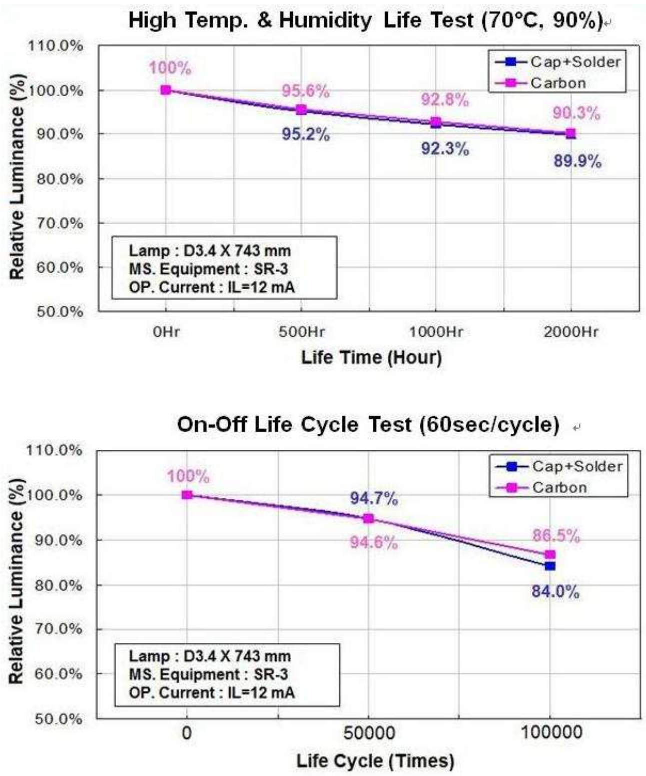

Figure 14. The life test results of developed EEFL.

Figures 13 and 14 show the relative luminance vs. life performance of CCFL 7mA vs. the newly developed EEFL 12mA driving conditions. The new design has a similar life test result and can achieve 60000h reliability of 50% luminance requirement under 12mA operating conditions.

Finally, we establish the theoretical background of a new design for manufacturing. It is important to make the manufacturer understand the development and the intentions of design to reduce trial and error. In my experience, the process report of MSD is a very powerful reference guide not only for checking for risks in design, but also for troubleshooting in manufacturing. However, while a well-described FMEA is a good reference for manufacturers, it is often extra work for design engineers, so the FMEA tends to be not well-described. However, the process report of MSD includes identification of failure detections, isolation and compensation of new designs through the MSD process. Additionally, other items to check are follows:

- Control plans and drawings for manufacturing.
- Perform maintainability analysis which documents the analysis, summarizes inconsistent design areas, and identifies special controls necessary to reduce failure risk
- Make recommendations to follow up on corrective action implementation /effectiveness.

MSD is helpful in bridging the gap between senior and junior engineers because MSD provides the detailed steps that we should know for good design.

4. CONCLUSION

The MSD (Mechanism Solution Design) process provides a more thorough method for solving design problems because it defines the issues as the gap between "desired results" and "current states" processes which are adaptable to every domain in AD. The determination of the functional/physical mechanisms process (this is for the set up and test of hypothesises method to introduce the best way to find mechanisms) reveals the explanation to the functional/physical mechanism of issues properly. The mechanism-based determination of solution process redefines the functional requirements more ideally, determine the design parameters and production variables according to the ideal design theorem of the Axiomatic Design and optimizes production variables to achieve a "Robust Design" that is easy to manufacture and achieves a more creative "good design".

Finally the design validation process should be performed in the aspects of reliability, and the process design and control for manufacturing.

As mentioned above, MSD proposes an evaluation method of FRs, a definition method of critical issues and an analysis method of mechanisms. Mechanism analysis is a natural process for professional engineers, but is not formally taught in most engineering programs. Therefore, MSD can help both new and experienced design engineers to avoid mistakes, reduce unnecessary issues and iterations in the design process, and achieve both creative results for the design and delivery of technological developments.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] Cho G. S., Lee J. Y., Lee D. H., Koo J. H., Choi E. H., Kim B. S., Lee S. H., Pak M. S., Kang J. G., Verboncoeur J. P, "Pinhole formation in capacitive coupled external electrode fluorescent lamps", *J. Phys. D: Appl. Phys.*, Vol.37, pp.2863-2867, 2004.

[2] Evan J. W., Evans J. Y, *Product Integrity and Reliablity in Design*, London: Springer, 2001, ISBN 1-85233-215-8.

[3] Gill D.-H, Song H. S., Kim J.-H., Kim S.-J., Kim S. B., Kim T.-Y., Yu D.-G., Koo J.-H., Choi E.-H., Cho G. –S., "The lifetime and pinholes in the external electrode fluorescent lamps", *SID '05 Digest*, pp.1312-1315, 2005.

[4] Heo et al., "Interactive System Design Using the Complementarity of Axiomatic Design and Fault Tree Analysis", *Nuclear Engineering And Technology*, Vol. 39, No.1 February, 2007.

[5] Matsushita, "External Electrode Fluorescent Lamps", 2005, Patent JP-P-2005-00312874.

[6] Ramo S, Whinnery J.R, and Van D. T., *Fields and Waves in Communication Electronics*, 3rd ed., John Wiley and Sons, New York, 1994. ISBN 0-471-58551-3.

[7] Suh N.P., *The Principles of Design*, New York: Oxford University Press, 1990, ISBN 0-19-504345-6.

[8] Suh N.P., *Axiomatic Design: Advances and Applications*, New York: Oxford University Press, 2001, ISBN 0-19-513466-4.

[9] Suh N.P., 1998, "Axiomatic Design Theory for Systems," *Research in Engineering Design,* Vol.10, No.4, pp.189–209, 1998.