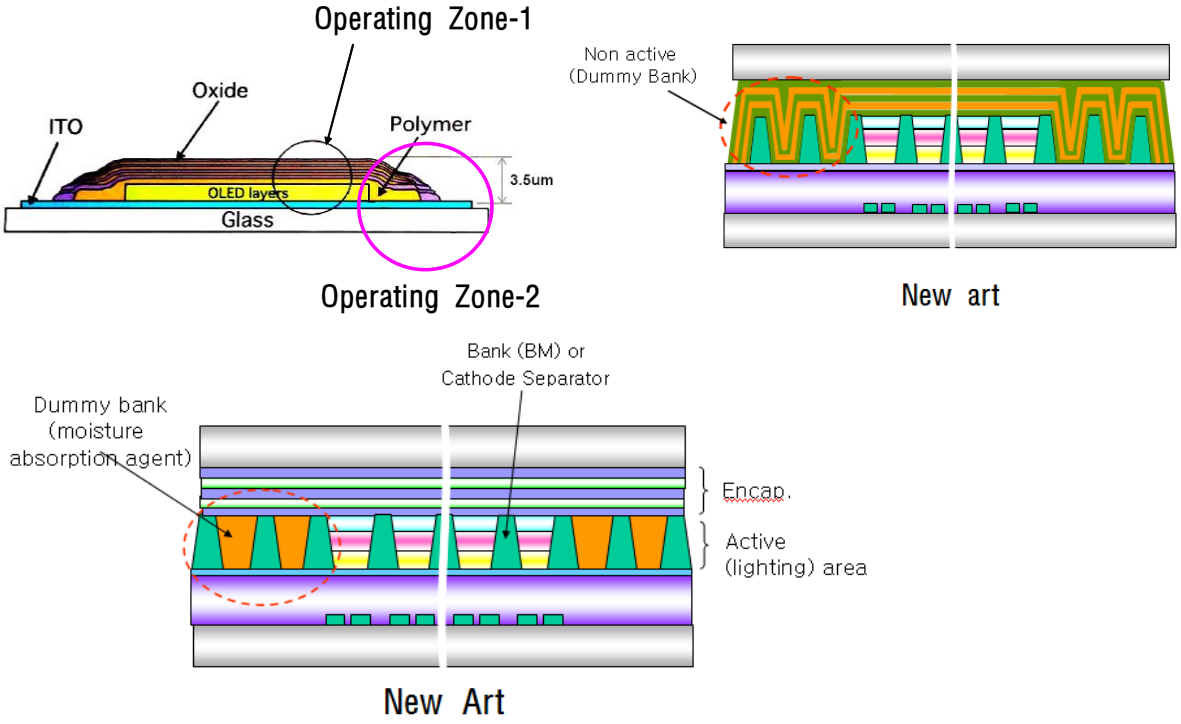
OLED Encapsulation

Abstract

<Insufficient moisture/oxygen barrier property > (problem) of <organic light emitting diode> (system name) with minimizing structure/manufacture complexity, was resolved by <changing geometrical/chemical feature of the encapsulant> is presented following ARIZ-85C [1] version template. Increasing functionality of encapsulation to stop moisture and oxygen was achieved by introducing moisture absorption material so called getter into bank area and layering into the dummy block which is located in the invisible part of the OLED, which reduces number of inorganic layers which makes the manufacturing procedure very complicated.



[1] ARIZ-85c by N. Khomenko

PART 1. THE PROBLEM ANALYSIS[2]

1.1. The mini-problem formulation

The encapsulation system in flexible OLED for **stopping oxygen/moisture** to **avoid OLED degradation** includes **substrate with TFT-circuit, OLED active layers, several organic layer, several inorganic layer, air, oxygen and moisture(main object of the encapsulation).**

Technical Contradiction 1 (TC1): If there is large number of inorganic layers, encapsulation system block oxygen and moisture **sufficiently (good),** but OLED system becomes rigid **(bad).**

Technical Contradiction 2 (TC2): If there is a few number of inorganic layers, OLED system does become non-rigid **(good),** but encapsulation system block oxygen and moisture **insufficiently (bad)**.

Goal: It is necessary with minimum changes in the system, to **block oxygen, moisture sufficiently (good)** with keeping the OLED system not rigid.**(good)**.

1.2. Definition of the conflicting elements[3]

Tool: inorganic layer (A)[4]

- **State 1 - TA:** multiple number of inorganic layers – ***A1***
- **State 2 -anti-TA:** a few (small number) inorganic layers – ***A2***

Product:

- moisture / oxygen - (B)[5]
- OLED system - (C)

[2] Referring to own problem extraction logic described in supplementary 2 of this paper, the author formulated a mini-problem according to the formulae of ARIZ-85c part 1.

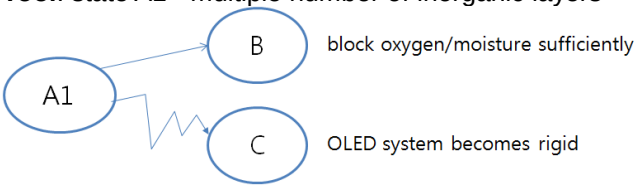
[3] This is the part to identify and formulate down the conflicting pair: tool and product which shows the core of the problem

[4] Inorganic layer is the main component which conduct primary function of encapsulation, "stop moisture" at the same time, making inorganic layer generating produces manufacturing complexity, that's why the authors has chosen inorganic layer as tool of conflict.

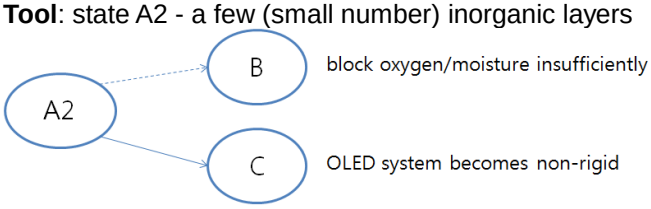
[5] It is necessary to "block moisture and oxygen" from the environment. The level/amount/concentration of moisture and oxygen are parameter to be minimized.

1.3. Description of graphic models for Technical Contradictions

TC1
Tool: state A1 - multiple number of inorganic layers



TC2
Tool: state A2 - a few (small number) inorganic layers



1.4. Selection of a graphic model for further analysis

The target system that the project team is developing is [flexible OLED]. Encapsulation is sub-system of the OLED to provide oxygen/moisture stopping function to increase long-life duration of OLED. As high level requirements for encapsulation is non-ritidity, TC2 was chosen as main model for further analysis.

1.5. Conflict intensification

TC2 - intensified

- **Tool** : **absent**[6] inorganic layer (A2-1)
- **Product**
  Product B: moisture and oxygen – no action to stop moisture and oxygen
  Product C: OLED system – no rigidity

[6] Intensify the conflict by indicating the extreme state (action) of the elements, which makes the conflict sharper not to compromise the usual solution, to deliver non-rigid OLED system, the author changed the tool condition from ‘a few’ to ‘absent’.

1.6. Summarize the problem model

1. The conflict pair

It is given:

- **Tool: absent** inorganic layer (A2-1)
- **Product:** moisture (with oxygen) and OLED system

2. Intensified definition of conflict

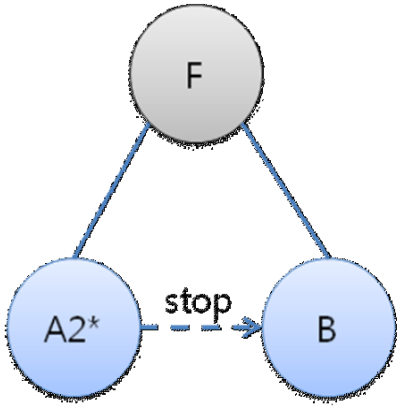
It is given an absent inorganic layer of the encapsulation and moisture (with oxygen). The absent inorganic layer does not produce non-rigidity and does not provide stopping moisture (with oxygen).

3. Goal

It is required to find an X-element that will keep ability of the absent inorganic layer does not produce non-rigidity and will provide protection from moisture (with oxygen).

1.7. Apply the inventive standards[7]

Su-field model of intensified conflict

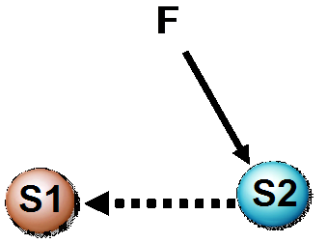
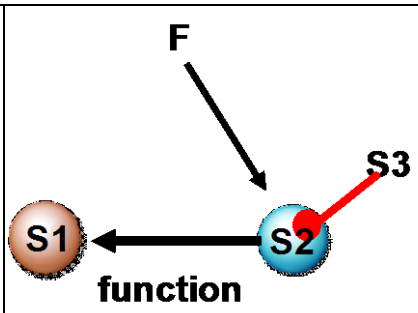


A2* : single encapsulation layer

B : moisture and oxygen

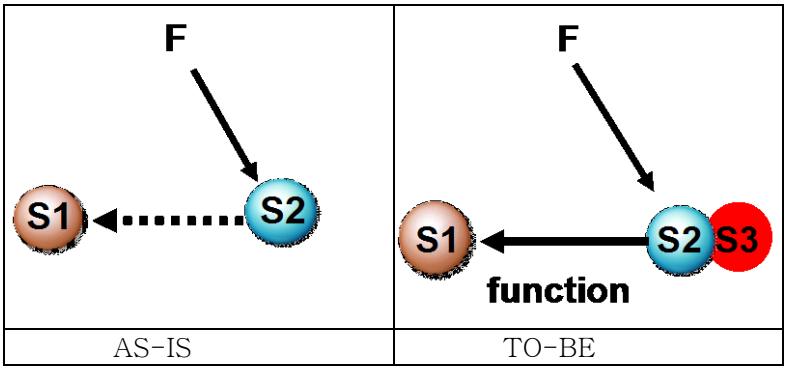
F : van der Waals force, ionic interaction etc.

Refer to Standard solution 1-1-2

	
AS-IS	TO-BE

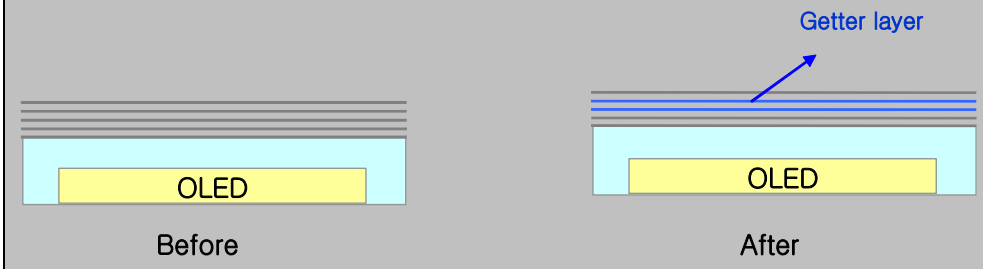
[7] This step provides important opportunities for solution direction according to standard solution, evolution patterns. Even classical inventive principles worked well enough in this stage. In real case, the author and the co-workers obtained many impressive ideas in this step.

Refer to Standard solution 1-1-3



AS-IS	TO-BE

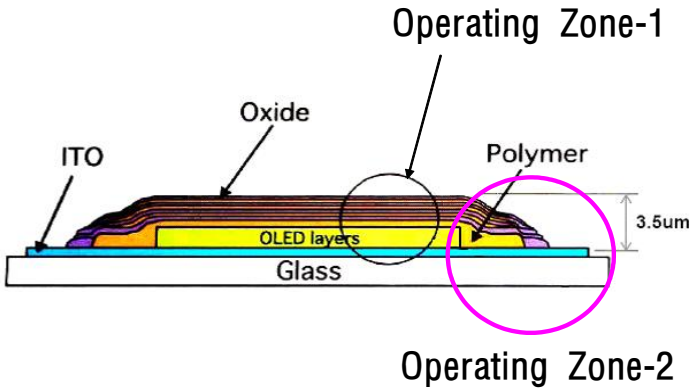
Concept 01 Getter layer inerstion



Instead of multiple "inorganic layer", make a single inorganic/organic layer with several layers of getter material of which function is absorbing moisture.

PART 2. ANALYZING THE PROBLEM MODEL[8]

2.1. Define the operational zone (OZ)[9]



Operating zone-1 of the encapsulation blocks moisture and oxygen onto the light generating part of the OLED.
Operating zone-2 of the encapsulation blocks moisture and oxygen from the side part of the OLED.

2.2. Define the operational time (OT)

In the problem about protection of OLED, there exist moisture and oxygen around OLED all the time after manufacturing. So operation time analysis does not lead good solution point.

[8] The main purpose of Part 2 is to identify available resources (space, time, substances, and fields) that may be useful for problem solving. Here the author extracted available resources from the result of preliminary resource multiscreen and resource table.
[9] Here the author focused on the area of "harmful action" between tool and product of the conflict. The most serious "harmful action" is insufficient stopping moisture and oxygen. The author classified the most risky area as operating zone 1, otherwise normal area as operating zone 2.

2.3. Define the substance-field resources (SFR)

Define the Substances and Fields Resources (SFR) of the analyzing system, the environment, and the product. Compose a list of SFR

	Substance	Field	Hidden resources[10]
System (Internal)	tool: single layer(combination of single organic layer and single inorganic layer) of encapsulation product: moisture and oxygen	intermolecular interaction(van der Waals force, ionic force etc)	
Available (External)	substrate bank LTPS TFT cathode lighting emitting layer anode driver IC	light of OLED electric field heat mechanical impact	Bank (color is black, lies on the invisible region)
supersystem	air, dust, hand oil black spot of light emitting layer	ambient light	
Manufacturing process	product: manufacturing process(complexity, cost)		manufacturing time storage time transfer time main working time non working time domestic room outdoor

[10] Hidden resources are existing resources without serious estimation for problem solving till now, i.e. unrecognized properties, features, function, information of substance and field. The author think it is one of most important action to expoloe hidden resources to solve conflict problem.

PART 3. DEFINING IDEAL FINAL RESULT (IFR) AND PHYSICAL CONTRADICTION (PhC)[11]

3.1. Formulate IFR-1

The X-element
Without complication of a system and without harmful side effects,
Eliminates

Absence of blocking moisture
During the Operational Time
Inside the Operational Zone: OZ-1, OZ-2,

and keeps the absent inorganic layer to provide non-rigidity of OLED system.

[11] In the part part 3, the author formulated ideal final result. According to designated IFR, more definite physical contradiction was induced. In the field consulting, many researchers provoked that IFR is too abstract and seems to useless in real practice, but I insisted to think the imaginary solution of their problem first before synthesizing full solution.

3.2. Intensify definition of IFR-1[12]

X-element is single layer itself (we select it from resources)
IFR-1-0
The absent layer itself
Without complication of a system and without harmful side effects,
Eliminates Absence of blocking moisture
During the Operational Time
Inside the Operational Zone: OZ-1, OZ-2,
and keeps the absent inorganic layer to provide non-rigidity of OLED system.

X-element: Moisture and Oxygen
IFR-1-1
The Moisture and oxygen itself
Without complication of a system and without harmful side effects,
Eliminates Absence of blocking moisture
During the Operational Time
Inside the Operational Zone: OZ-1, OZ-2,
and keeps the absent inorganic layer to provide non-rigidity of OLED system.

X-element: bank
IFR-1-2
The bank itself
Without complication of a system and without harmful side effects,
Eliminates Absence of blocking moisture
During the Operational Time
Inside the Operational Zone: OZ-1, OZ-2,
and keeps the absent inorganic layer to provide non-rigidity of OLED system.

X-element: substrate
IFR-1-3
The substrate itself
Without complication of a system and without harmful side effects,
Eliminates Absence of blocking moisture
During the Operational Time
Inside the Operational Zone: OZ-1, OZ-2,
and keeps the absent inorganic layer to provide non-rigidity of OLED system.

[12] To intensify IFR-1, it is necessary to choose appropriate resources as candidates of X-element. According to classical TRIZ, most recommendable resources as X-element are internal resources, - tool, product, field and property generated by tool and/or product and so on. So in the process of thinking, the first candidate of X-element was chosen as the product or the conflict element, i.e. moisture and oxygen. Among external resources, substrate and band are the cheapest resources in the whole resources. It is just basis material of all. So 2nd and 3rhd candidates of X-elements were chosen as substrate and bank.Other resources should be considered later because it is necessary to change many features of the related systems if we introduce other resources.

3.3. identify the Physical Contradiction for the macro-level

Template:

<Name of Resource> in the <Operating zone>, during the <Operational time>, has to… <indicate physical macro-state, for example "hot"> in order to perform <indicate one of the conflicting actions> and has to <indicate the opposite physical macro- state, for example "cold"> to perform <to indicate another conflicting action or requirement>.

X-element:single layer itself

macro PhC-1

Absent inorganic layer itself
in the OZ-1, OZ-2,
during the operation time
has to be thin
in order to provide non-rigidity of OLED system and
has to be thick
to <enhance absent stopping function of moisture and oxygen >.

X-element:moisture

macro PhC-2

moisture/oxygen itself
in the OZ-1, OZ-2,
during the operation time
has to be thin
in order to provide non-rigidity of OLED system and
has to be thick
to <enhance absent stopping function of moisture and oxygen >.

X-element:bank

macro PhC-3

bank itself
in the OZ-1, OZ-2,
during the operation time
has to be thin
in order to provide non-rigidity of OLED system and
has to be thick
to <enhance absent stopping function of moisture and oxygen >.

3.4. identify the physical contradiction for the micro-level

Template:

there should be particles of a substance <indicate their physical state or action> in the Operational Zone in order to provide <indicate the macro-state according to step 3.3> and there should not be the particles (or particles should have the opposite state or action) in order to provide <indicate another macro-state according to step 3.3>

X-element: absent inorganic layer itself
Micro PhC 1
Absent inorganic layer itself
in the <OZ-1, OZ-2>,
during the operation time,
has to be thin and free from any other substances (small aggregation tendency)
in order to <provide non-rigidity> and
has to have additive substances (big aggregation tendency)
to enhance absent function of stopping moisture and oxygen .

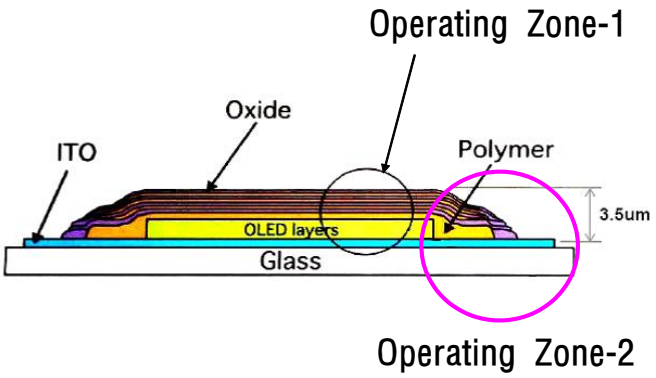
X-element:moisture
micro PhC 2
<moisture/Oxygen itself>
in the <OZ-1, OZ-2>,
during the operation time,
has to be thin and free from any other substances (small aggregation tendency)
in order to <provide non-rigidity> and
has to have additive substances (big aggregation tendency)
to enhance absent function of stopping moisture and oxygen

X-element:bank
micro PhC 3-1
<bank itself>
in the <OZ-1, OZ-2>,
during the operation time,
has to be thin and free from any other substances (small aggregation tendency)
in order to <provide non-rigidity> and
has to have additive substances (big aggregation tendency)
to enhance absent function of stopping moisture and oxygen

micro PhC 3-2 (geometrical consideration)
<bank itself>
in the <OZ-1, OZ-2>,
during the operation time,
has to be thin and free from any other substances (small aggregation tendency)
in order to <provide non-rigidity> and
has to have additive substances (big aggregation tendency)
to enhance absent function of stopping moisture and oxygen

3.5. Formulate IFR-2[13]

X-element: absent inorganic layer itself
IFR-2-0
<Absent inorganic layer by itself>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**



X-element: moisture
IFR 1
<moisture and oxygen>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**

X-element: bank
IFR 2-1
<bank>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**
.

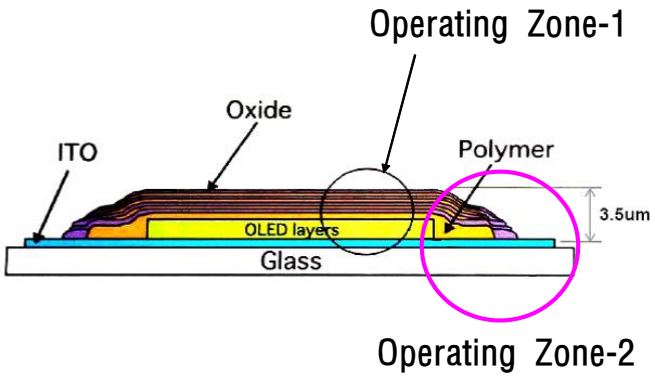
[13] Ideal Final Result (IFR-2) was identified using the following pattern: The Operational Zone <indicate> has to provide <indicate the opposite macro- or micro-states> itself during the Operational Time <to indicate it>.

IFR 2-2
<bank>
in the <OZ-2>,
during the operation time,
has to be provide small aggregation tendency in order to <provide non-rigidity> and
has to have big aggregation tendency to enhance absent function of stopping moisture and oxygen

IFR 2-3
<bank> in the <OZ-2>,
in the <OZ-2>,
during the operation time,
has to be provide small aggregation tendency in order to <provide non-rigidity> and
has to have big aggregation tendency to enhance absent function of stopping moisture and oxygen.

3.6. Apply the inventive standards to resolve physical contradiction[14]

X-element: absent inorganic layer by itself
IFR-2-0
<absent inorganic layer by itself>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**

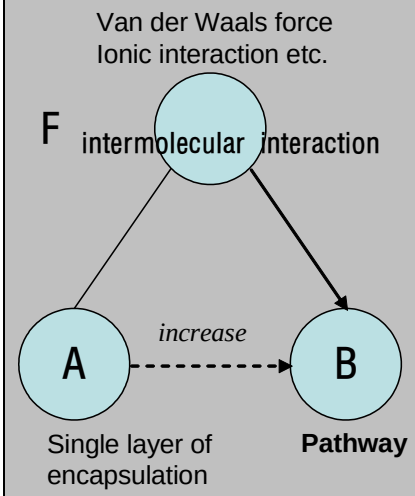


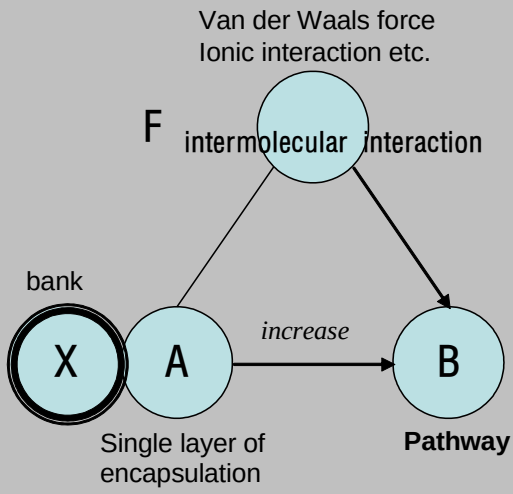
X-element: moisture
IFR 1
<moisture and oxygen>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**

X-element:bank
IFR 2-1
<bank>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**

[14] At this stage the author checked possibility to apply the Inventive Standards to solve the new Physical Problem that formulated as the IFR-2. Even if the author could have good solutions at this stage, the author progressed ARIZ to the next stage to shake up mental inertia.

Concept 02. Physical wall to stop moisture penetration

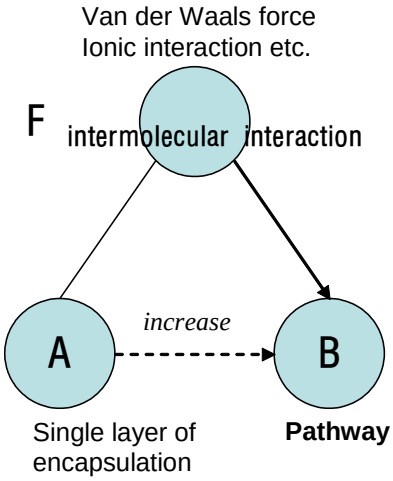




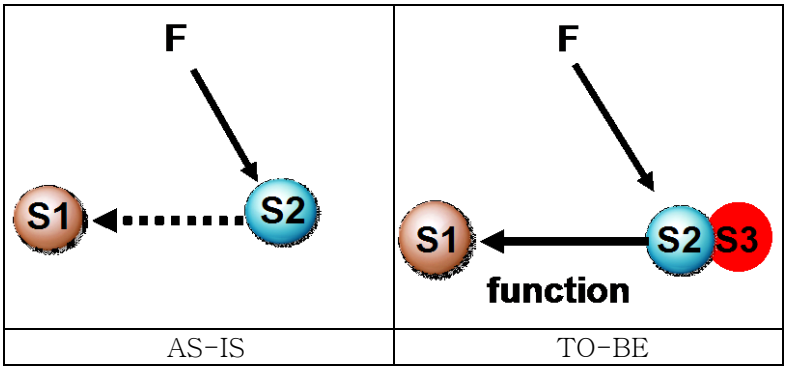
By introducing bank for moisture and oxygen to go around, it is possible to increase pathway distance of moisture and oxygen from outside to inside of the encapsulation. Bank should have the dimension of macro scale barrier for moisture and oxygen.

BEFORE AFTER

Su-field model



Refer Standard solution 1-1-3



AS-IS	TO-BE

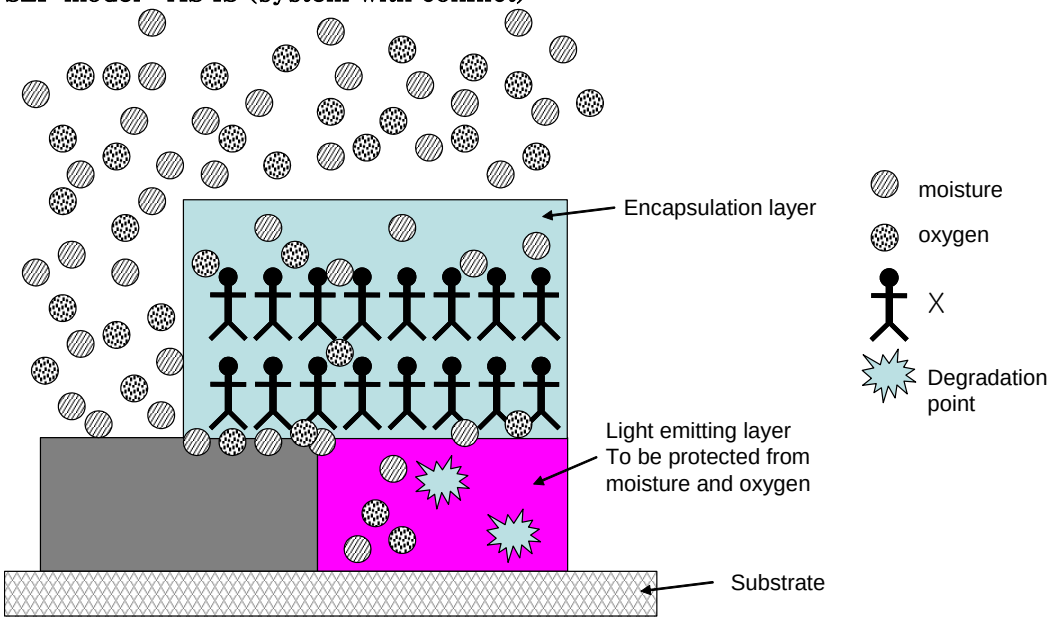
IFR 2-2
<bank>
in the <OZ-2>,
during the operation time,
has to be provide small aggregation tendency in order to <provide non-rigidity> and
has to have big aggregation tendency to enhance absent function of stopping moisture and oxygen

PART 4. MOBILIZING AND UTILIZING OF SUBSTANCE-FIELD RESOURCES (SFR)[15]

4.1. Simulation with little creatures[16]

IFR 2-1
<x>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**

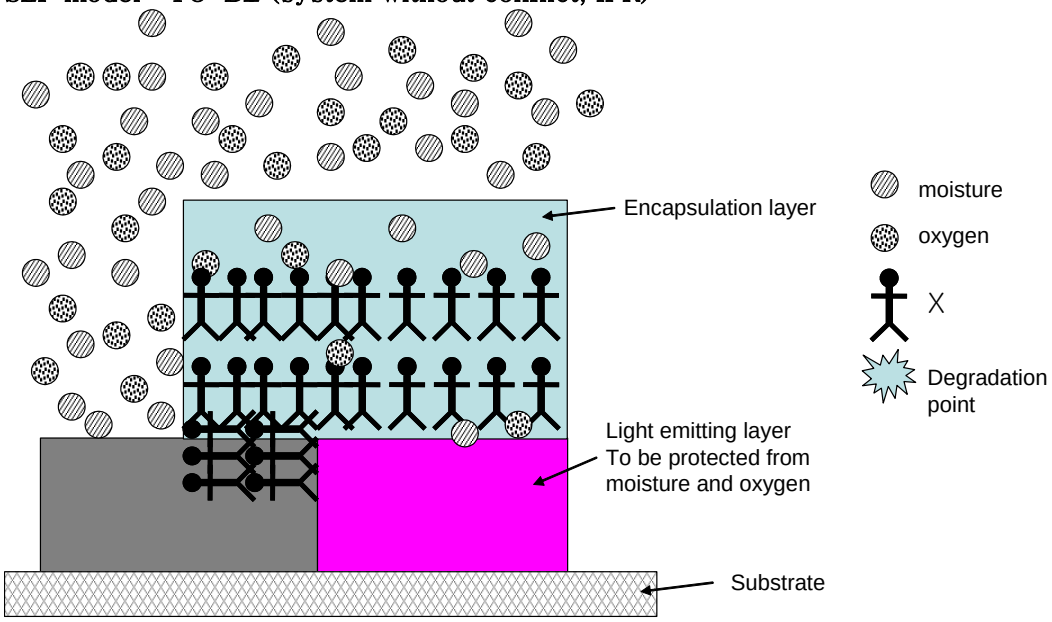
SLP model : AS IS (system with conflict)



[15] At the step 2.3, the available resources, which can be used "free of charge", were identified. Part 4 of ARIZ includes systematic procedures to increase availability of resources. It is considered the derivative SFR that can be obtained almost free of charge through slight modification of the already available resources. Steps 3.3-3.5 began the transition from the problem to the solution based on applying of physics; Part 4 continues this direction.

[16] At this stage the author figured out graphic model of conflict using the Simulation with Little People (SLP), moreover the author figured out new graphic model without conflict. Drawing TO-Be modela as well as AS-IS model was very effective to show off the mental process of TRIZ thinking way to the high level manager: so the author recommended field researchers to figure out at least one scene of IFR as SLP model.

SLP model : TO-BE (system without conflict, IFR)



4.2. To take a "step back" from IFR[17]

4.3. Using combination of substance resources[18]

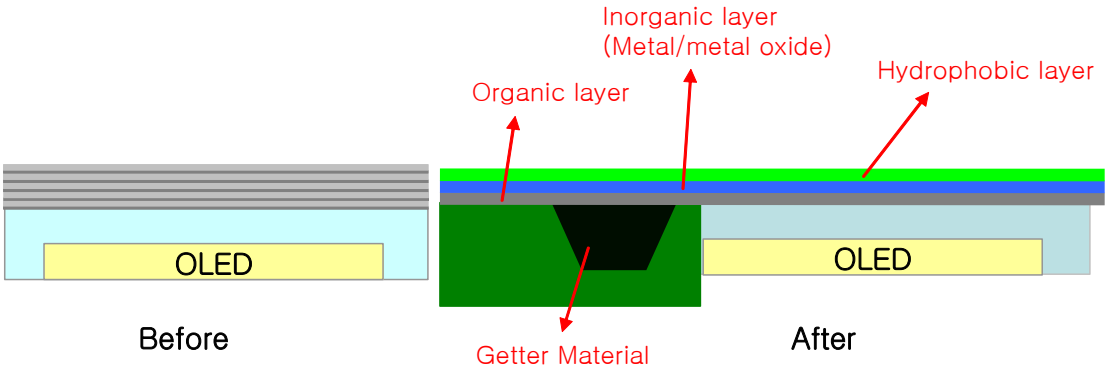
IFR-
<bank>
in the <OZ-2>,
during the operation time,
has to be provide **small aggregation tendency** in order to <**provide non-rigidity**> and
has to have **big aggregation tendency** to **enhance absent function of stopping moisture and oxygen**
.

[17] If it is known what the desired system has to be (from description of problem conditions) and the problem is to find way to achieve this system, it might be helpful to "step back" from the Ideal Final Result. The desired system is described, after which some minimum disassembling change is applied. Personally, step by step back from IFR is the most favorite route for solution generation.
[18] When taking step back from IFR, the author checks the ability to hybrid of existing resources.

4.4. Using "void"[19]

IFR : think “void”, i. e. invisible part of bank
<bank> in the <OZ-2>, during operation time
has to <make **short pathway for moisture and oxygen** by itself>
and <layer with **20 long pathway for moisture and oxygen**> has to <enhance insufficient stopping moisture and oxygen > during <T1, T2>.

Concept 03. Getter in the bank



By introducing special material which make cake when it meet moisture and oxygen(conventional name of this material is "getter"), it is possible to enhance moisture stopping ability of the layer.

4.5. Using derived resources[20]

Consider hybrid and derived substance resources

4.6. Using an electrical field

Consider possibility e-field or two interacting electrical fields instead of substance.

4.7. Using a field and field-sensitive substance

Consider "field + substance additive that responsive to this field" pair.

[19] The author checks possibility to solve problem by replacing the existing substance resources with an empty space or a mixture of substance resources and empty space as well as “hidden part” of the space resources. In this case, the author focused on the hidden part in the prior part of the ARIZ, this step was skipped.
[20] The remaining steps of part 4 were skipped because the author and project team obtained appropriate numbers of solution with good enough quality before this stage.

PART 5. APPLYING THE KNOWLEDGE BASE[21]

5.1. Applying the system of standard solutions for inventive problems

Consider possibility to solve problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying Inventive Standards.
NA

5.2. Applying the problems-analogous

Consider possibility to solve problem problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying solution concepts to non-standard problems, that have already been solved using ARIZ.
NA

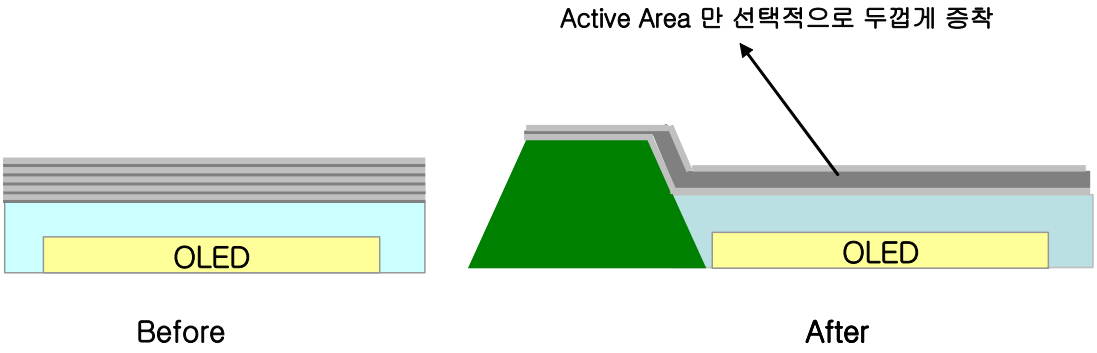
5.3. Applying the principles for resolving the physical contradictions

Consider possibility to resolve Physical contradiction using the typical transformations (see Table 2. Principles for resolving the Physical Contradictions)

Concept 04. Selective thick layer

- Resource: ceramic layer
- Trigger : separation by space,

The area to prevent moisture/oxygen penetration is active region. If ceramic layer is thick on the active region, we may reduce moisture/oxygen penetration into the active area. If non-active area coating is thin, flexibility of over-all level can be preserved.



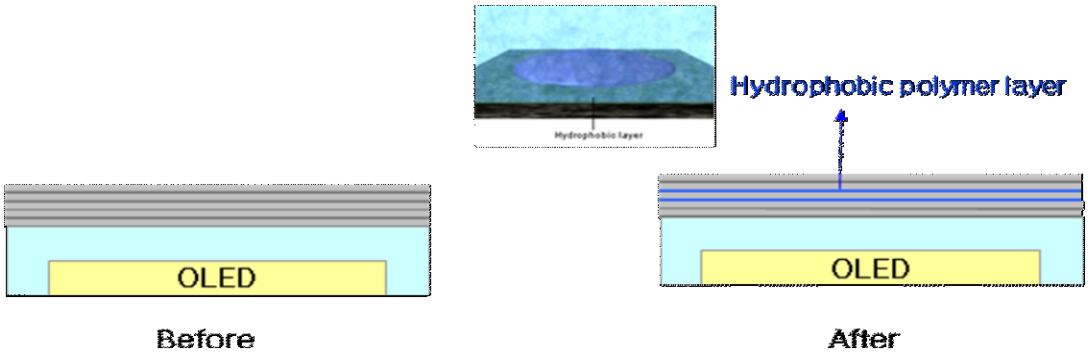
5.4. Applying the pointer to physical effects and phenomena

The author also checked several physical and chemical effects (for example, hydrophobicity).

Concept 05. Hydrophobic layer insertion

- Resource: hydrophobic polymer layer (for example, PDMS, transparent Teflon)
- Trigger: physical effects

[21] In many cases, Part 4 of ARIZ helps to achieve a solution concept, so it is possible to go to Part 7 of ARIZ. If no solution is achieved after step 4.7, Part 5 is recommended. The purpose of Part 5 of ARIZ is to mobilize all experience accumulated in the TRIZ knowledge base. The problem is significantly clearer at this point so it is very likely that direct utilization of the knowledge base will be successful.

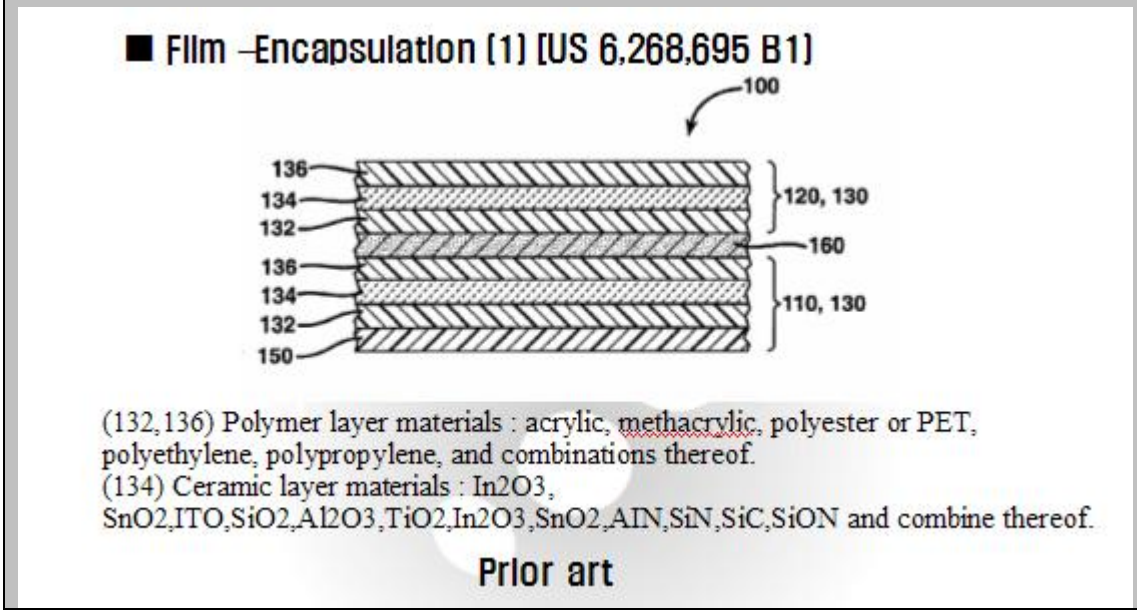

Hydrophobic polymer layer
Hydrophobic layer
OLED
OLED
Before
After

PART 6. CHANGING OR SUBSTITUTING THE PROBLEM[22]

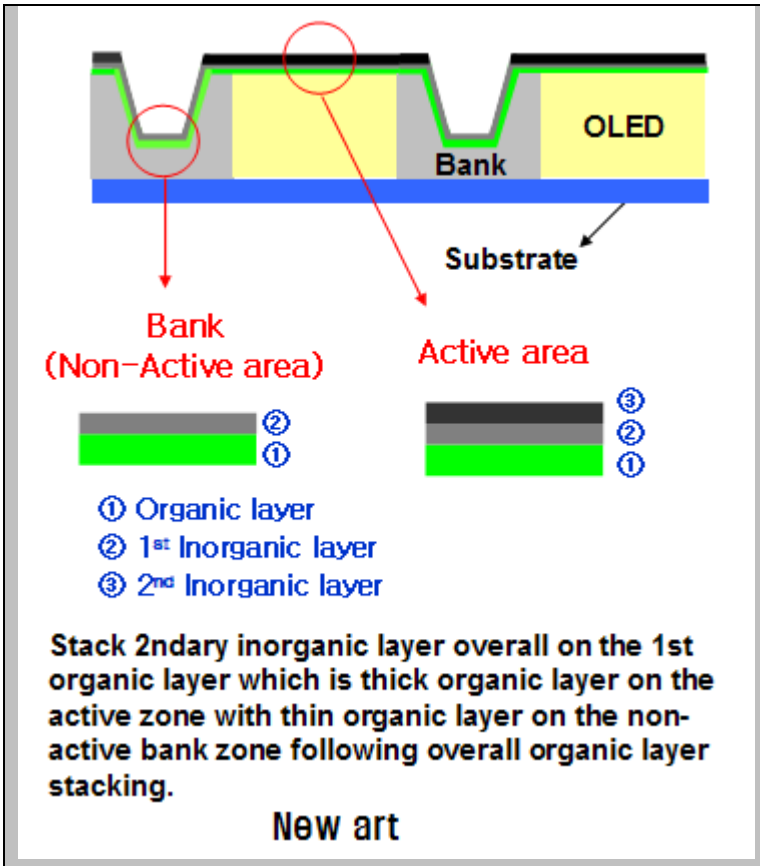
6.1. Transition to the technical solution

If the problem is solved, transfer the physical solution concept into a technical one: formulate the principle of action and develop a schematic diagram of device that implements this principle.

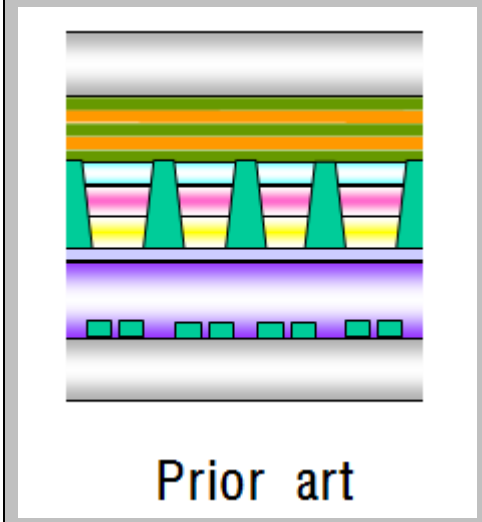
Technical Solution 1. Selective thin film encapsulation
(KP2006-0010594, RD-200511-063-1)
Source. Concept 4.



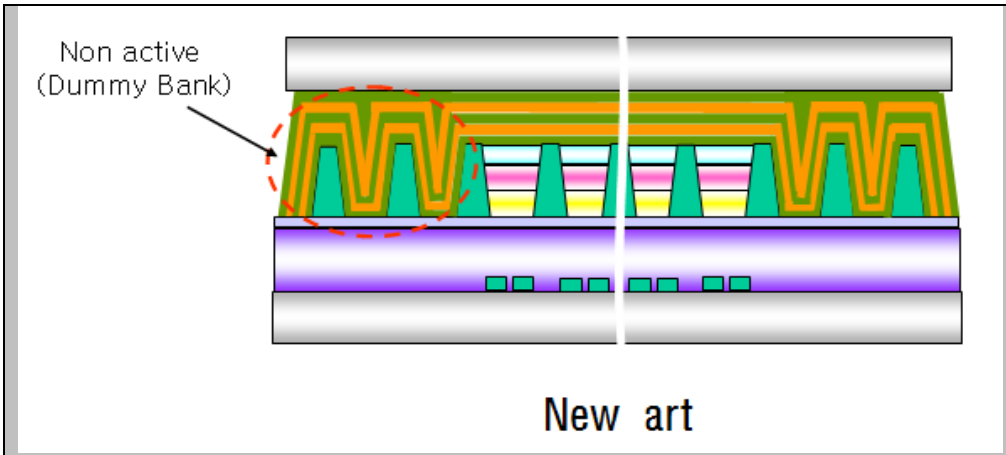
[22] This stage is decision making step. Here the author had chosen good enough solution, i.e. solution for physical contradiction were transformed to real solution.



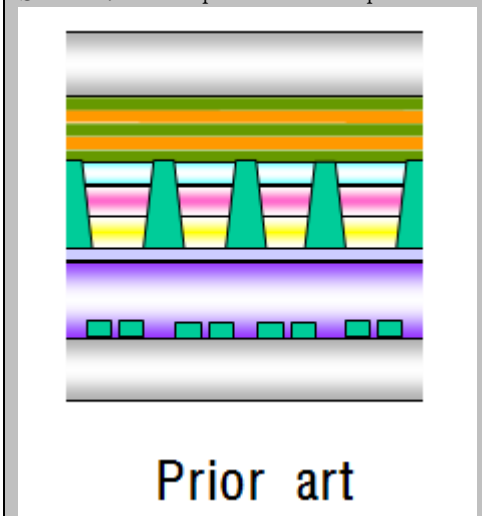
Technical solution 2. Stop side moisture penetration
KP2006-0003118
RD-200511-059-1
Source. Concept 2.

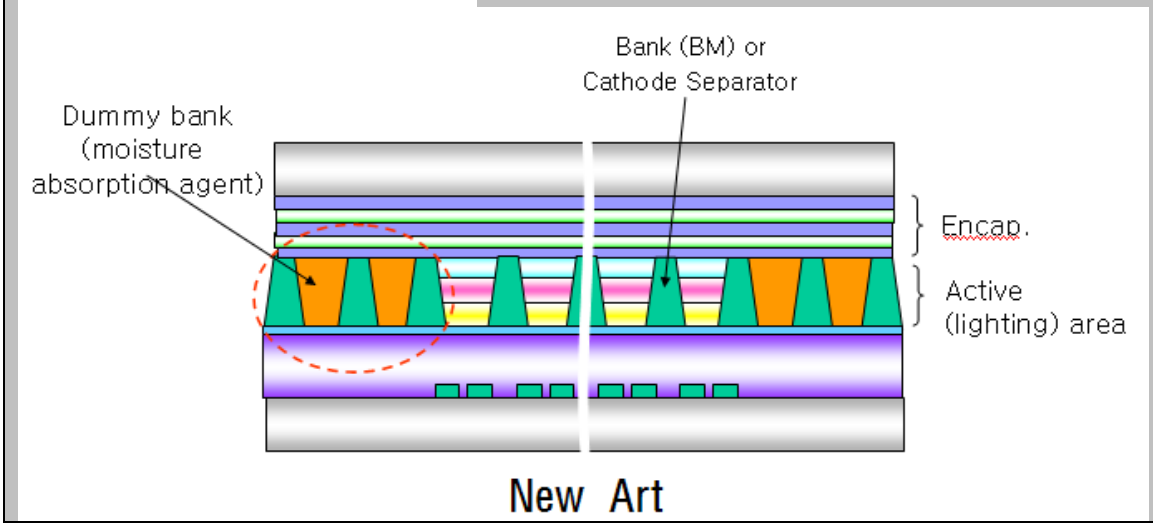


By adding additional dummay back at the side of the OLED. Moisture/oxygen penetration length can be increased which decrease moisture/oxygen absorption into light generating part.



Technical solution 3. Moisture absorption agent in the bank
KP2006-0003120
RD-200511-061-1
Source. Concept 1 + concept 3





6.2. Checking the problem formulation for combination of several

problems

If the problem is not solved, check to see whether the description in Step 1.1 represents a combination of several problems. In this case, it is necessary to reformulate the step 1.1, by extracting separated problems. Those problems have to be solved one after another (often it is enough to solve just a main problem).

NA

6.3. Changing the problem

If the problem is not solved, change the problem by selecting another Technical Contradiction in step 1.4.

NA

6.4. Reformulation of mini-problem

If the problem is not solved, return to step 1.1 and reformulate the Mini-Problem with respect to the super-system. If necessary, repeat this reformulation process with the next several successive super-systems.

NA

PART 7. ANALYZING THE METHOD OF RESOLVING THE PHYSICAL CONTRADICTION[23]

7.1. Checking the concept of solution

Control question (through 7.1)	Techncial solution 1	Techncial solution 2	Techncial solution 3
Is it possible to apply available or derived SFRs instead of introducing the substances/fields?	yes	Yes	Yes
Can self-controlled substances be applied?	no	no	no

7.2. Preliminary estimation of the solution concept

Control question (through 7.2.~7.4)	Techncial solution 1	Techncial solution 2	Techncial solution 3
7.2.1. Does the solution concept provide the main requirement of IFR- 1 (the element without complication of a system...)?	yes	yes	Yes
7.2.2. Which Physical Contradiction (if any) is resolved by the solution concept?	yes	yes	Yes
7.2.3. Does the new system contain at least one easily controlled element? Which element? How is it controlled?	yes	yes	Yes
7.2.4. Does the solution concept found for "single-cycle" Problem Model fit the real conditions, multi-cycle conditions?	multi	multi	multi

7.3. Checking the priority of the solution concept through patent funds

Control question (through 7.2.~7.4)	Techncial solution 1	Techncial solution 2	Techncial solution 3
7.3. Does the solution have novelty? (via patent search)	yes	yes	yes
Korea Patent Number	0707210 (2007.04.06)	0647339 (2006.11.10)	0647340 (2006.11.10)

[23] The main purpose of Part 7 of ARIZ is to check quality of obtained solution concept. The Physical Contradiction should be resolved almost ideally, "without nothing". It is better to spend an additional two or three hours to obtain a new, more powerful solution concept than to fight half of lifetime with weak, difficult to implement idea.

US Pub. No.	20070181872 (2007.08.09) Organic light emitting display and manufacturing method thereof	20070159089 (2007.07.12) FLAT PANEL DISPLAY DEVICE	20070159096 (2007.07.12) FLAT PANEL DISPLAY DEVICE AND METHOD THEREOF
Remarks	As one of inventors	As facillitator	As facillitator

7.4. Estimation of sub-problems to implement obtained solution concept[24]

Control question (through 7.2.~7.4)	Techncial solution 1	Techncial solution 2	Techncial solution 3
7.4. What kind of sub-problems exist that might require invention, design, calculation, the overcoming of organizational challenges?	Not so serious	Not so serious	Not so serious

[24] What sub-problems might appear during embodiment design of the new technical system?
Write down those possible sub-problems that might require invention, design, calculation, the overcoming of organizational challenges, etc.

PART 8. APPLYING THE OBTAINED SOLUTION

The real innovative idea not only solve the particular problem, but also provides a universal "key" to many other analogous problems. The purpose of Part 8 of ARIZ is to maximize utilization of resources unveiled by obtained solution concept.

8.1. Estimate of changes for super-system

Define how the super-system that includes the changed system should be changed.

Control question	Techncial solution 1	Techncial solution 2	Techncial solution 3
8.1. How the super-system (that includes the changed system) should be changed?	Mfg process order/detailed experimental arrangement should be changed.	Mfg process order/detailed experimental arrangement should be changed.	Mfg process order/detailed experimental arrangement should be changed.

8.2. Find new application for obtained solution

Check whether the changed system or super-system can be applied in a new fashion.

Control question	Techncial solution 1	Techncial solution 2	Techncial solution 3
8.2. Can the changed system or super-system be applied in a new fashion?	yes	yes	Yes

8.3. Apply solution concept for other problems[25]

One of the best principle of solution of this project is "utilizing hidden part of the bank(side part)". The author calls this principle as one small part of step 4.4. utilizing void. Void is trivial resources for any cases, so word "consider void" did not induce novel thinking. But check "unseen part of the neighboring element" triggers field researchers to make attention to the "right resources". Dimensionality change principle of Classical inventive principle archive (no.17) is very similar to the core solution principles of this project.

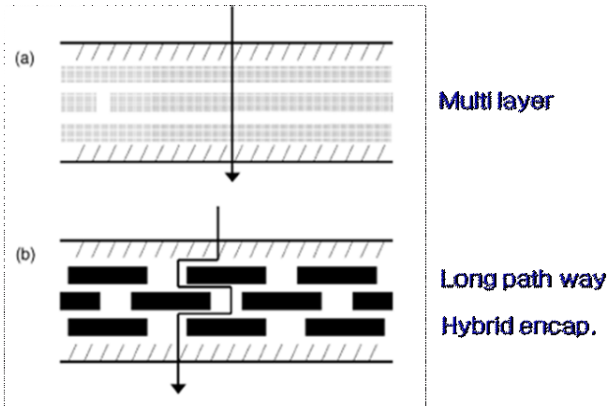
There is one important solution principle in this project: that is "increasing distance between harmful solurces and critical place" designated in technical solution 1 ~ 3.

[25] Apply the solution concept to solving other problems:

- Formulate a general Solution Principle.
- Consider direct application of the Solution Principle to other problem solving.
- Consider applying the opposite Principle to other problems.
- Create a morphological matrix (e.g. "parts location" versus "phase states of the product" or "applied fields" versus "phase states of the environment", etc.) that includes all possible modification of the solution concept, and consider every combination produced by the matrix.

Consider the modifications to the Solution Principle that would result from changing the dimensions of the system or its main parts, imaging the result if dimensions were to approach zero or stretch toward infinity.

"Increasing distance between harmful solurces and critical place" was one more time applied to the different project to deveop thin barrier film for LCD by different team. Instead of just inserting multi-layers to stop moisture penetration across the film with small barrier power which have favorable compatibility with the matrix polymer, the authors inserted multiple layers which make segrated domain in the matrix with high hydrophobicity.Schematic diagram of this concept is as following.



PART 9. ANALYZING THE PROBLEM SOLVING PROCESS[26]

9.1. Compare proposed process and real

Compare the real process of problem solving with the theoretical one (that is, according to ARIZ). Write down all, if any, differences.

Just using ARIZ 85c, it was very difficult to extract mini-problem from real project. So the author and colleagues had developed pre-ARIZ logic coherent with DFSS(design for six sigma) process (see Part 0 of this report).

The later part of part 4 was sometimes redundant comparing to Standards or inventive principles. The author considers it is necessary to apply evolution laws/patterns in the appropriate steps.

9.2. Compare obtained solution concept and knowledge from TRIZ

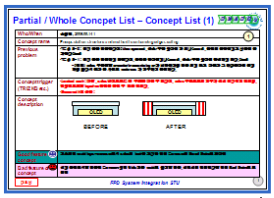
Compare the obtained solution concept to the information in the TRIZ knowledge base (Inventive Principles, Inventive Standards, and Pointer to Physical effects and phenomena).

If the knowledge base does not include a principle that applies to obtained solution concept, document this principle into preliminary knowledge base.

skipped

[26] As ARIZ text says about this chapter, problem solving according to ARIZ process helps the authors see the problem from the different angles. The author agrees, ARIZ using is not enough to increase 'creative potential' but it is necessary to 'reflect ARIZ using'.

Supplementary 01
Concept list(33)



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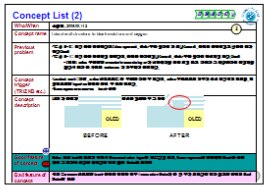

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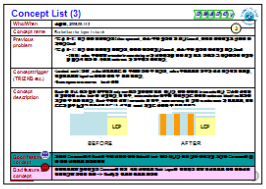

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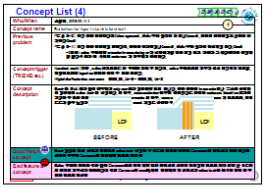

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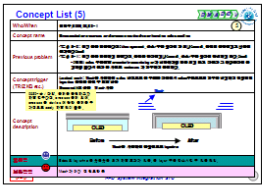

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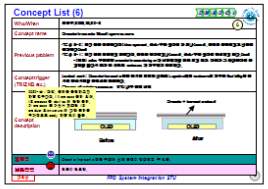

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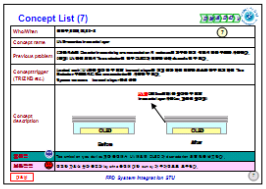

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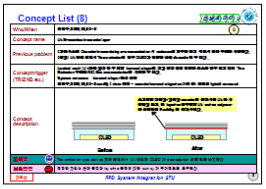

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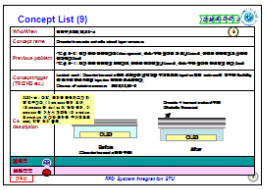

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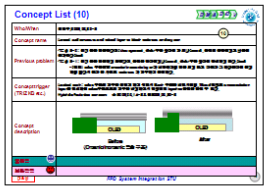

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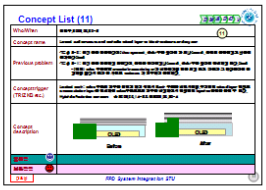

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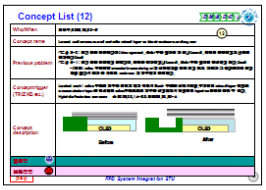

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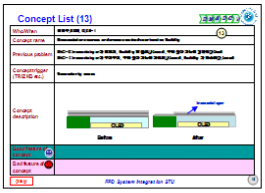

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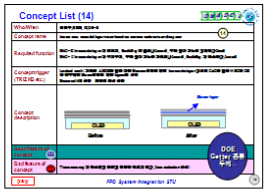

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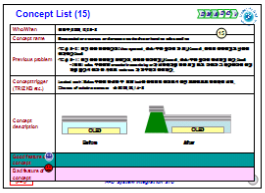

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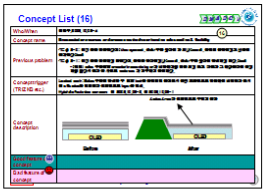

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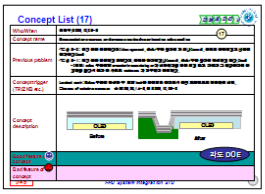

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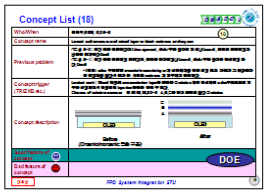

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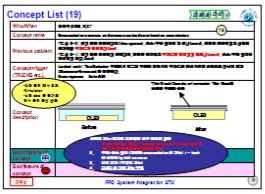

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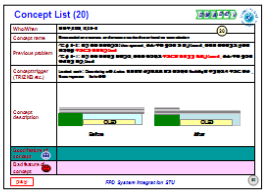

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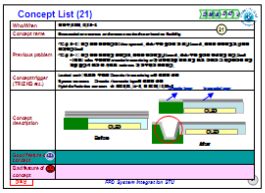

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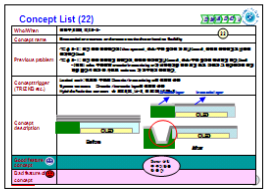

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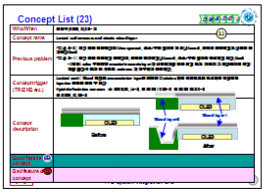

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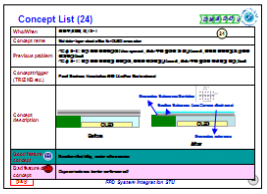

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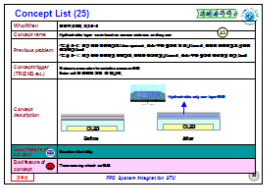

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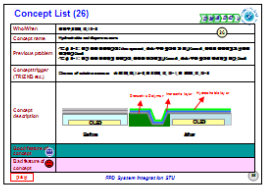

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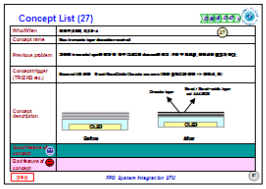

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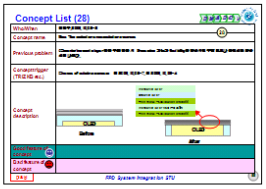

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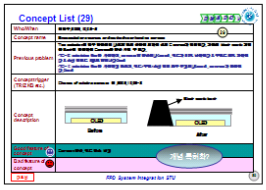

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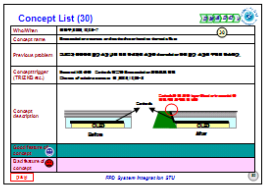

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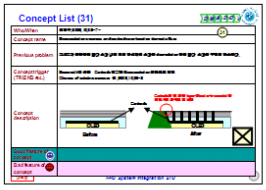

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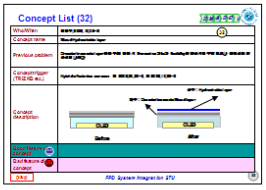

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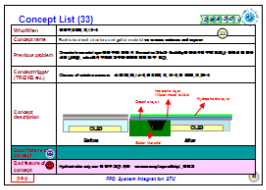

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Supplementary 2

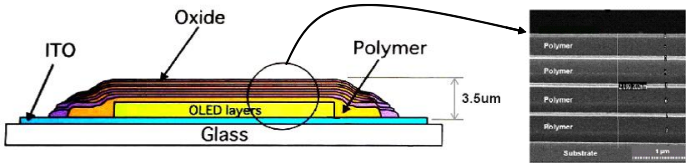
PART 0. IDENTIFY INVENTIVE PROBLEMS[27]

0.0. Description

- *Project Objective: Concept Design of thin film flexible encapsulation*
- *Project Period: 2005. 09. 05 ~2005. 11.09*
- *Benefit: novel patent positioning,33 reduce manufacturing cost*
- *Member: Mr. Lee, Young Koo (project leader) with 6 temporary-residential meeting members*
- *Consultant: Song, Mi Jeong, Ph.D.*

A. Brief problem description

State of the problem



Light emitting organic materials in Organic Light Emitting Diode (OLED) degrades with reaction of oxygen/moisture. As the result of the reaction the material of OLED becomes non-light emitting. It is necessary to stop moisture/ambient air penetration from environment. Encapsulation fulfils a function of stopper for moisture/air penetration during operation and non-operation period of OLED. In most general case the encapsulant is stainless steel can or glass can. But flexible display requires flexibility as well as stopping moisture/oxygen. Usual flexible encapsulation made of organic material has poor barrier function of moisture and oxygen. Current best competing system, Vitex system uses two different materials to provide both of barrier property and flexibility. To block moisture/oxygen penetration, Vitex system uses inorganic layer. To provide flexibility of whole encapsulant, Vitex system introduces organics layer. To meet the spec of barrier property, it is necessary to use several folds of organic and inorganic layers.33 It is very difficult manufacturing process to make several folds of organic and inorganic layer. Yield of this operation is very low. Penetration through alternating organic/inorganic multi-layer is very low. However, oxygen/moisture penetration from lateral side of this layer is so big to provide appropriate barrier property. Moreover, mechanical property of these alternating organic/inorganic layers is poor.

B. Purpose of the project:

To create patent free technology for 'flexible' oxygen/moisture barrier encapsulant module

C. Constraint of the project:

Requirements to protective layer:
- Flexible;
- Easy in manufacture;
- does not change parameters of OLED

D. History of solving the problem

- SUS can as solution
- Glass/ ceramic CAN
- Film CAP
- Hybrid CAP

[27] *Song et al., Hands-on logic for problem solving – 0 & I., TRIZ-Journal, October, 2004*

E. Criteria for selection of solution concepts

Screening criteria	good direction
Water vapor transmition rate (WVTR)	The smaller the better
Oxygen transmition rate (OTR)	The smaller the better
Strength	The higher the better
Light management ability	The more various option the better
thermal deformation	smaller the better
flexibility	higher the better
manufacturing easiness	easier the better
enlarging capacity	larger the batter
thickness/weight	smaller the better
novelty	should be novel

F. Team building
Skipped

G. Milestone
Skipped

0.1. Modeling technical system

A. **System hierarchy**

System name: OLED encapsulation

Target object

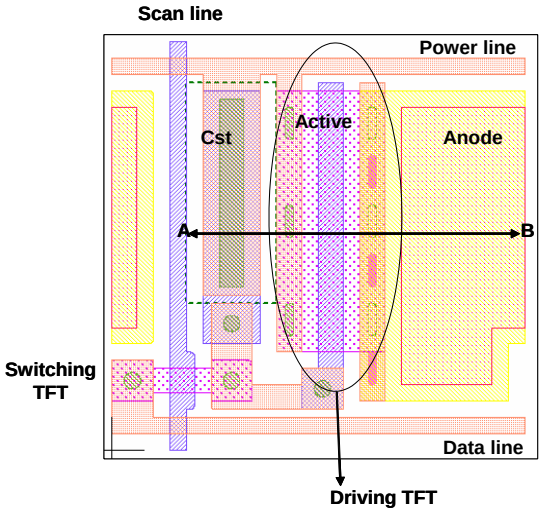
- moisture
- oxygen
- mechanical field

Function

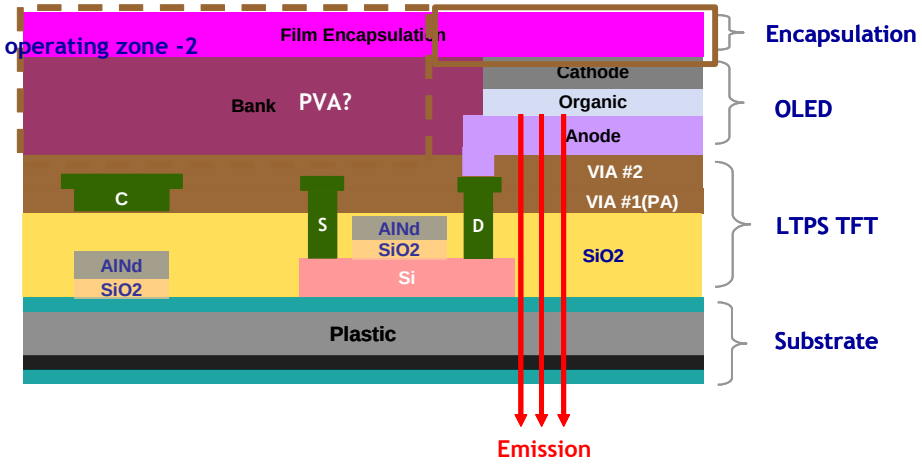
- primary function : stop [oxygen, moisture, mechanical field]
- attractive function or feature : Flexible, light, thin, cheap,

System structure (O^{28})

Top view



Side view



1. Substrate, bank : ? Flexible AM-OLED System[29]
2. LTPS TFT

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[28] In the beginning of system analysis, OLED system was analyzed before to understand the purpose and objective and requirements for OLED encapsulation module.

[29] Project team focused on flexible display. Therefore thin and flexible system should be considered. Until then, multiple sandwich films of organic/inorganic layers was the best know solution for this purpose.

3. Display Part (OLED): cathode, light emitting layer, anode
4. Encapsulation: organic layer
5. Driver IC

Supersystem

- TFT Array,
- Flexible Substrate,
- OLED,
- Encapsulant (Inorganic/Organic alternating layer)

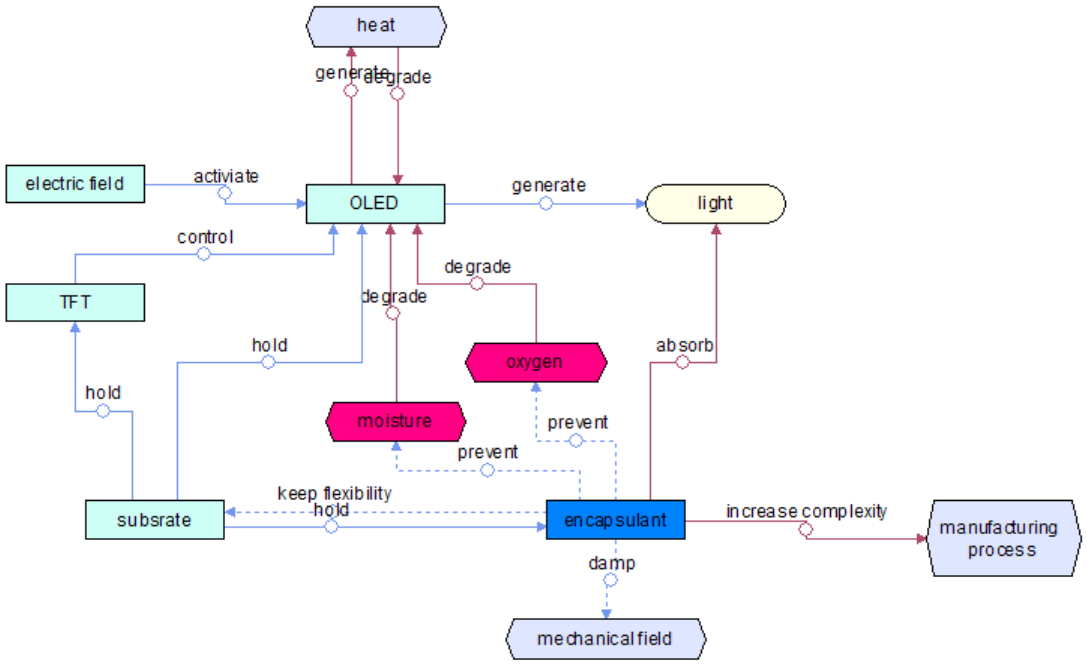
Environment

- Harmful by-products : heat
- Accidental occasion : mechanical impact, vibration
- background : electric field, air, external light

B. system analysis[30]

- If target system is a device or unit process, system analysis should be conducted by function analysis.
  - If target system is a manufacturing process or a series of functions, system analysis should be conducted by process analysis. Even if target system is a process, unit process could be analyzed by function analysis schema.

B1. Function analysis



AL: Functions “prevent”, “keep flexibility”, “increase complexity” are incorrect.

B2. Process analysis[31]

Skipped because not interesting scope

C. Problem model-stage 1[32]

Needs of supersystem	Existing UDF (undesirable function/process)	Problem priority
Increase life-time of OLED	Oxygen and/or moisture degrades light generating (primary function) layer of OLED.	High

[30] If target system is a device or unit process, it recommended formulating function analysis diagram. If target system is a process of flow, it is recommended formulating process analysis and/or root cause analysis first.

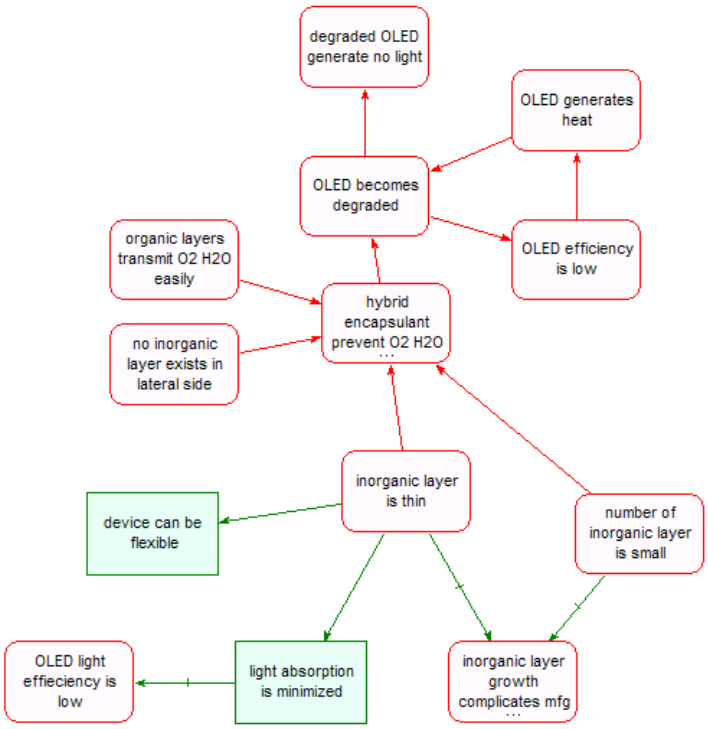
[31] Skipped not because it is less important, but because manufacturing process was out of the interesting scope within the period of the annual project phase.

[32] The author prefers problem model formulation step by step, this is the first stage of problem modeling from the needs of customers in the supersystem.

0.2. Determining cause/effect of undesirable function(s)[33]

Toolkit: root- cause- analysis in Goldfire Innovator etc. or problem formulator in IWB

A. Root -cause diagram



[33] The author prefers root cause analysis according to problem formulator in IWBTM because problem formulator covers "counter-action" for problem relation as well as conventional cause-effect relationship.

B. Problem model-stage 2

Needs of supersystem	Existing UDF (undesirable function/process)	Root cause of UDF	Problem priority
Increase of OLED lifetime	Oxygen, moisture degrades light generating layer of OLED.	Encapsulation stops oxygen, moisture insufficiently	High

0.3. Preliminary resource analysis[34]

Toolkit: Multi-screen and/or resource table could be used for preliminary resource analysis if necessary, not mandatory part

A. Multi-screen

Supersystem	NA	substrate, bank, LTPS TFT, cathode, lighting emitting layer, anode, driver IC	NA
System	Manufacturing process	Main operating process	Maintenance process
Subsystem	NA	organic layer inorganic layer	NA
	Past/previous	Now/current	Future/next

[34] Multi-screen and/or resource table summarizes preliminary resources if necessary. This is not mandatory part of the pre-ARIZ logic of the author.

B. Resource table

Resource type	Supersystem	System	Subsystem
Substance	substrate bank LTPS TFT cathode lighting emitting layer anode driver IC oxygen moisture air dust, hand oil	hybrid encapsulation	organic layer inorganic layer
Field	electric field, generated light, heat, mechanical field external light(sun etc)	electric field, light, heat, mechanical field	electric field, light, heat, mechanical field
Time		manufacturing time storage time transfer time main working time non working time	
Space		In the room Outdoor	
Condition			
Function			
Information			
etc			

0.4. Apply Transition Action (TA) to fix up at least 'single undesirable function' (needs)[35]

Needs of supersystem	Existing UDF (undesirable function/process)	Root cause of UDF	Transition action
Increase of OLED lifetime	Oxygen, moisture degrades light generating layer of OLED.	Encapsulation stops oxygen, moisture insufficiently	Increase number of layers

Transition Action: Increase number of layers

0.5. Formulating good/bad effects of the TA to system/supersystem,

- GOOD to system. : Encapsulation stops oxygen, moisture sufficiently
- BAD to supersystem/previous system. : Manufacturing process becomes very complex

0.6. Evaluating priority of problem models[36]

Needs of supersystem	Existing UDF (undesirable function/process)	Root cause of UDF	Transition action	Good effect of TA	Bad effect of TA	Priority
Increase of OLED lifetime	Oxygen, moisture degrades light generating layer of OLED.	Encapsulation stops oxygen, moisture insufficiently	Introduce several ceramic layers between film layer by layer	Encapsulation stops oxygen, moisture *sufficiently*	Structure becomes complex which needs complicated manufacturing process	2
					Flexibility of encapsulation decreases which makes OLED non-flexible	1

[35] Generally, technical contradiction could be obtained simply with varying value of system patermers and evaluation good/bad effet of system parameter variation. But in the very beginning stage of R&D project, it is hardly know/set the value of the system parameter as well as evaluate the effect of the parameter value change. So the author suggested the other route to identify technical contradiction by introducing design perturbation action so called transition action, which could be induced by the solution of other fields of common sense.

[36] In real cases, there are several transition actions and results/effects chains of transition action. Evaluating the weight of priority of the 'bad effect of transition action', the author secreened the transition action which matches appropriate system evolution direction.

0.7. Technical contradiction formulating[37]

TC1

TA. Increase number of inorganic layers

- GOOD. Encapsulation stops oxygen, moisture sufficiently
- BAD. Flexibility of the whole OLED system decreases.

TC2

Anti TA. Decrease number of inorganic layers

- BAD. Encapsulation stops oxygen, moisture insufficiently
- GOOD. Flexibility of the whole OLED system increases.

[37] The final result of pre-ARIZ logic of the author is several sets of technical conflicts with its own priority/importance factor.

Related works

KP0707210 (2007.04.06)
app.no. 2006-001059443 (2006.02.03)
US 20070181872 (2007.08.09)
Organic light emitting display and manufacturing method thereof
app. no. 2006-50086743 (2006.08.08)
inventors
Lee, Young-gu(Seoul, KR)
Kang, Sung-kee(Seongnam-si, KR)
Oh, Tae-sik(Suwon-si, KR)
Lee, Ho-nyeon(Seongnam-si, KR)
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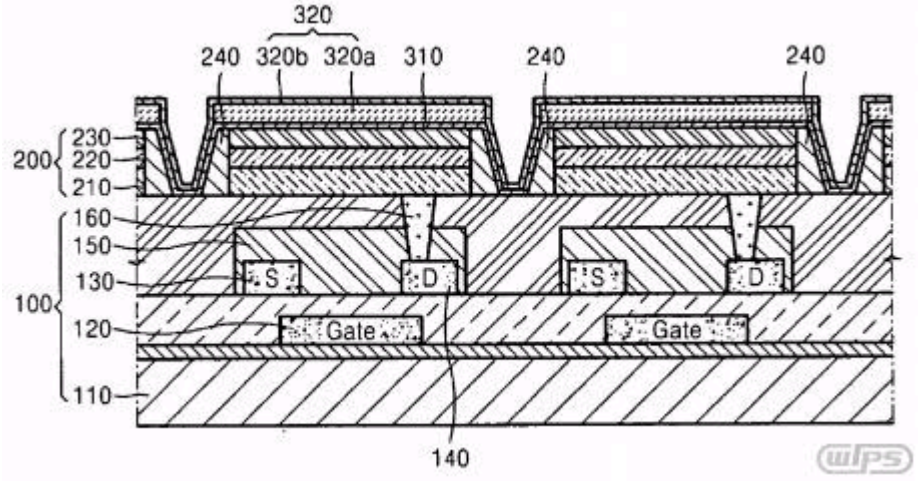
Chun, Young-tea(Suwon-si, KR)
Song, Mi-Jeong(Suwon-si, KR)
abstract

An organic light emitting display and a manufacturing method thereof include an improved encapsulation layer. The encapsulation layer of the organic light emitting display includes an organic layer uniformly covering bank portions and light emitting areas on a substrate; and an inorganic layer formed thicker on the light emitting areas than on the bank portions. In the organic light emitting display, the inorganic layer is thick on the light emitting area in which a sealing ability is required and the bank portion is thin in order to provide flexibility. Therefore, the encapsulation layer can be formed more easily compared to an encapsulation layer on a device in which the organic layer and inorganic layer are alternately formed at least 10 times.



claims

1. An organic light emitting display comprising:
a plurality of light emitting areas between bank portions on a substrate; and
an encapsulation layer covering the light emitting areas and bank portions, wherein the encapsulation layer comprises:
an organic layer uniformly covering the bank portions and the light emitting areas; and
an inorganic layer formed thicker on the light emitting areas than on the bank portions.

2. The organic light emitting display of claim 1, wherein the inorganic layer comprises:
a first inorganic film substantially uniformly deposited on the organic layer; and
a second inorganic film deposited substantially only on the first inorganic film above the light emitting areas.

3. The organic light emitting display of claim 1, wherein the inorganic layer comprises:
a first inorganic film deposited substantially only on the organic layer above the light emitting areas; and
a second inorganic film uniformly deposited on the organic layer and the first inorganic film.

4. The organic light emitting display of claim 1, wherein each of the bank portions have a recessed shape and are each disposed between the light emitting portions.

5. The organic light emitting display of claim 4, wherein the recessed shape results in a progressive reduction of a thickness of each bank portion on opposing sides forming substantially a V-shaped cut out.

6. The organic light emitting display of claim 1, wherein the organic layer is formed of one of acrylic, methacrylic, polyester polyethylene terephthalate, polyethylene or polypropylene.

7. The organic light emitting display of claim 1, wherein the inorganic layer is formed of one of In 2O 3, SnO 2, ITO (Indium Tin Oxide), SiO 2Al 2O 3, TiO 2, In 2O 3, SnO 2, SiN, SiC, or SiON.

8. A manufacturing method of an organic light-emitting display including:
forming a plurality of light emitting areas and a plurality of bank portions on a substrate, contiguous light emitting areas having a corresponding bank portion therebetween; and
forming an encapsulation layer covering the light emitting areas and the bank portions by uniformly covering the bank portions and the light emitting areas with an organic layer, and forming an inorganic layer to a greater thickness on the light emitting areas than the bank portions.

9. The manufacturing method of claim 8, wherein the forming of the inorganic film includes:
forming a first inorganic film on the organic layer substantially uniformly; and
forming a second inorganic film substantially only on the first inorganic film above the light emitting areas.

10. The manufacturing method of claim 8, wherein the forming of the inorganic film includes:
forming a first inorganic film substantially only on the organic layer above the light emitting areas; and
forming a second inorganic film on the organic layer and the first inorganic film substantially uniformly.

11. The manufacturing method of claim 8, wherein each of the bank portions are formed in a recess shape between contiguous light emitting areas.

12. The manufacturing method of claim 9, wherein the recessed shape results in a progressive reduction of a thickness of each bank portion on opposing sides forming substantially a V-shaped cut out.

Acknowledgement

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