

# Why-why Analysis of yet to Be Created Technical System

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## *Abstract*

*Why-why analysis is an established way of defining the problem in the technical systems that already exist. This article describes how this technique can be used for the synthesis of the technical systems. The core of the proposed version of the why-why analysis is considering the potential ways of performing the required function which are legitimate but not acceptable due to the project limitations. The new technique allows to apply a proven problem definition approach for the frequent case where the system is yet to be created.*

## *Keywords:*

*Why-why analysis, prediction, technical system, synthesis.*

## **Background**

This article describes the application of the why-why analysis to the frequent situation when there is a function which needs to be performed but the system for performing this function is not yet known. It is easy to assume that why-why analysis is not a suitable tool for defining problems in such situations. I have found, however, that why-why analysis is an excellent tool for problem definition in yet to be created systems once a certain way of performing the function is defined. This way does not have to solve the problem or address the inventive situation. The purpose of this way is to reveal a why-why contradiction which can be resolved using one of the TRIZ tools such as Principles or Functional Clues. This solution often leads to a useful and non-obvious concept of the new system. The ways of performing the required function can be found in the prior art, generated during a brainstorming session or result from a trial-and-error approach. The two requirements to this known way are: 1) to be able to perform the required function and 2) to dissatisfy one or more of the project limitations. More ways can be used to increase the number of the new system concepts resulting from the proposed approach.

## **Case Study: How to Separate a Semiconductor Wafer from the Stack?**

This is how the inventive situation is described in [1]: “The manufacture of semiconductor parts, or “chips”, typically begins with the processing of wafers made from silicon, gallium arsenide, or other semiconductor compounds. Initially,

a crystalline (or polycrystalline) boole is sawn simultaneously into several hundred thin wafers using means such as a wire frame saw. The wafers are typically quite thin, of the order of 200 microns thick, and are most often of circular cross-section. His sawing produces a stack of wafers contaminated with sawdust and sawing fluid. The wafers must then be removed from the stack, cleaned, and placed into a product carrier such as a cassette or tray before further processing.

Removing the wafers from the stack is typically done manually because the wafer material is brittle. Rough handling can easily result in breakage, or chipping of the edges, which would render the wafer useless for further manufacture. To prevent such damage, vacuum “wands” are commonly employed as a means for manually lifting individual wafers from the stack. A wand typically consists of a stem with an internal channel for vacuum, a broad tip, and a vacuum actuator switch for connecting the stem to a vacuum source. An operator picks up a wafer by placing the broad tip of the wand in the center of the planar surface of the wafer, thereby allowing the vacuum to cause the wafer to adhere to the wand. The operator can then transport the wafer from one location to another, and can then release the wafer by shutting off the vacuum to the wand.

Although adequate, manually separating wafers has a number of drawbacks. The wafers in a stack have a tendency to stick to one another, primarily due to surface tension effects. A wand alone cannot overcome these effects, requiring the operator to slide the wafers apart by pushing against their edges. This handling can damage the wafers. Furthermore, the labor required is a significant processing cost and takes considerable time.” An automated method for safe handling of the semiconductor wafers is therefore desirable.

### **Technique of Why-why Analysis of yet to Be Created Technical System**

The core of the proposed version of why-why analysis is considering the potential ways of performing required functions which are legitimate but not acceptable due to the project limitations. Known why-why analysis technique [2] begins by defining the starting point and project limitations. In our case, when the

system is yet to be created, the starting point is the main function of this future system. Project limitations are defined as usual. As the analysis progresses, additional limitations, revealed by the analysis, can be added to the original list. For our case study, the main function is “*separate wafer (from the stack)*”. This is the initial list of the project limitations:

- the wafers and the number of them in the stack cannot be changed;
- manual intervention is not allowed;
- damage to the wafers cannot exceed 1:20,000;
- doubles, triples, etc. cannot exceed 1: 20,000;
- capital cost of the unit cannot exceed \$100,000;
- the floor space area cannot exceed 4' x 3'.

The why-why analysis shown below (Figs. 1 – 3) allowed to reveal additional limitations which were not obvious before this analysis was done:

- the semiconductor material cannot be changed;
- the wafers must be in a stack.

As mentioned above, the proposed version of why-why analysis uses potential ways of performing required functions. A primary route for obtaining these potential ways is studying prior, especially patent, art. The ideas generated during a brainstorming session can also be utilized, along with the ideas randomly originated by the members of the project team. With all of these sources, the objective is to create an information pool for the problem understanding rather than to find a solution.

For our case study, the prior art offers some ways of performing the function “*separate wafer (from the stack)*”, such as the way used by the apparatus described in [3]. This apparatus uses a dam and jets of fluid, such as water or oil. The jets push the top wafer up and over the dam while the rest of the wafers are restrained in the stack by the dam. A feed unit continuously lifts the stack, eventually exposing each wafer to the jets. This method is faster than the manual separation but it still leads to significant wafer damage by forcing the thin and fragile wafer

edges against the rigid dam. This method also causes wafer damage by sliding of the top wafer against the next one. In effect, the method is capable of performing the required function but it does not meet one of the project limitations (damage to the wafers cannot exceed 1:20,000).

Another way of separating disk-like objects resembling semiconductor wafers – CDs and DVDs – from the stack is mentioned in the prior art description of [4]. According to this reference, the spacers can be inserted between the disk-like objects to prevent them from sticking to one another. Since the disk-like objects are pre-separated by the spacers, taking the top disk without affecting the stack becomes possible. However, this solution cannot be directly applied to our case study since it does not meet another project limitation (capital cost of the unit cannot exceed \$100,000) since a sub-system for inserting, removing and circulation of the spacers alone would require similar investment.

Finally, various mechanical pickup designs are known in the prior art which attempt to separate and lift the uppermost disk-like object from the stack by means of inserting thin prongs or blade-like elements between this object and the rest of the stack and pulling the uppermost object upwards. This is also a possible way of performing required function which, however, does not meet two of the project imitations (damage to the wafers and the amount of multiples).

The why-why analysis of yet to be created system is done by assuming that the required function is performed by one or more ways defined at the previous step. The rest of the analysis (revealing hidden whys, defining the boundaries of the analysis, wording why-why contradictions and defining the Problem Map) is the same as described in [2]. Figs. 1 - 3 show the why-why diagrams for three of the above-described ways of performing the function “*separate wafer (from the stack)*”. Each why-why analysis leads to multiple solutions. Each of the ways of performing the required function results in its unique solutions. More ways can be analyzed if additional solution alternatives are needed.

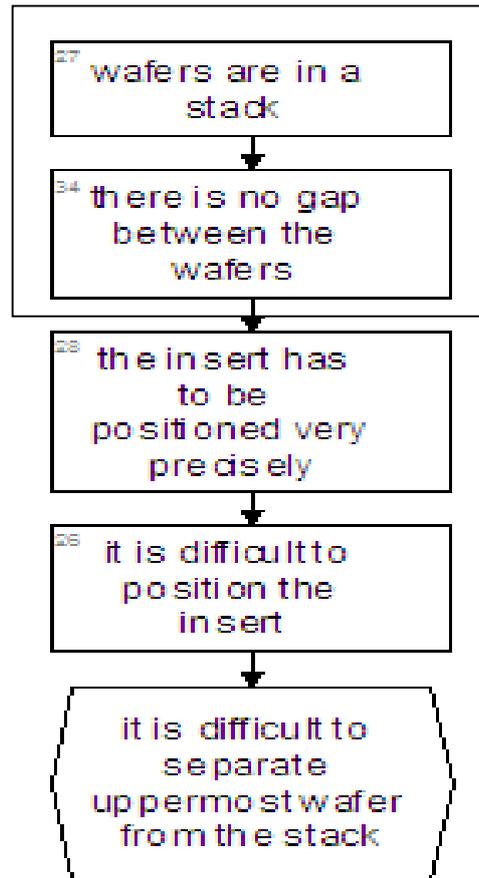


Fig. 1. Why-why diagram of wafer separation by an insert such as a flat prong or blade

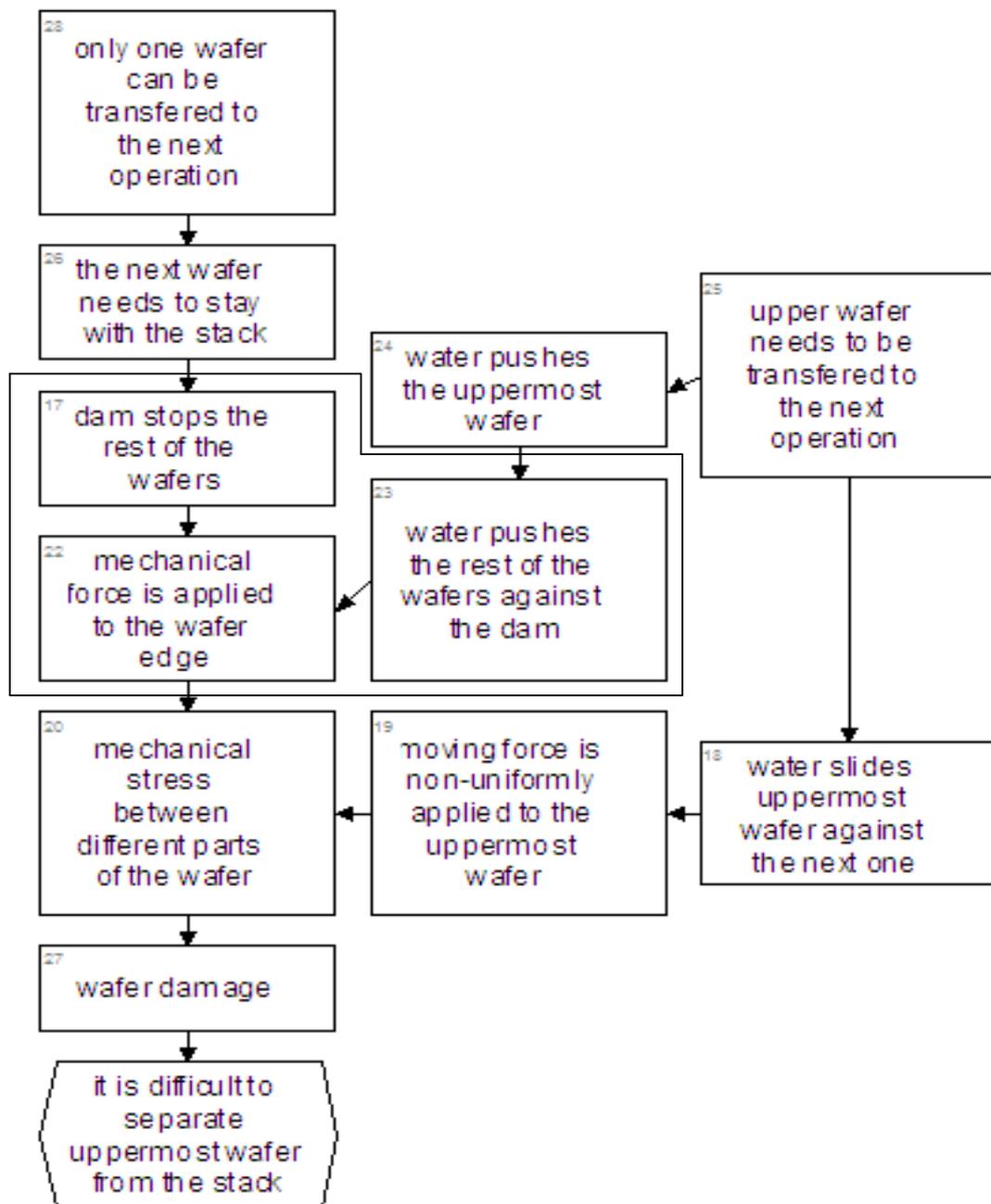


Fig. 2. Why-why diagram of wafer separation by a flow of liquid and a dam

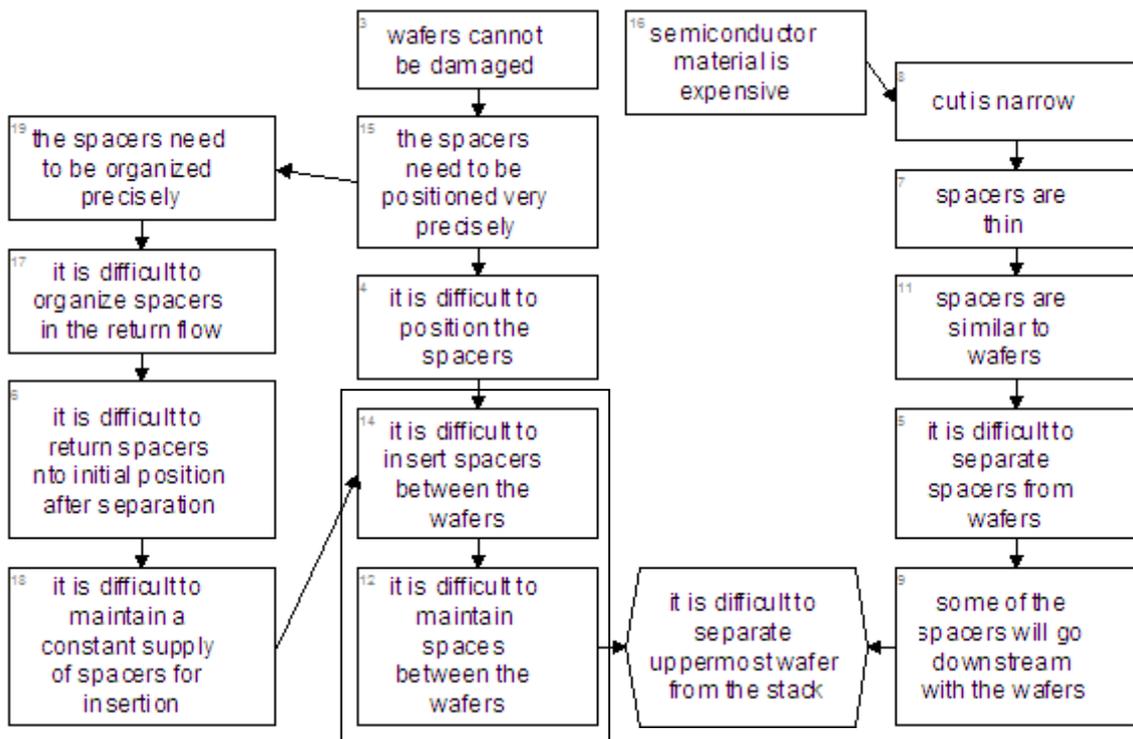


Fig. 3. Why-why diagram of wafer separation by the spacers

## Synthesis of a New System Based on Why-why Analysis Results

Let us see what kinds of new systems can be synthesized based on why-why analysis done as described in the current article. I will refer to Figs. 1 – 3.

### *Air Jet Separator*

One of the why-why contradictions derived from the analysis shown in Fig. 1 is “how to create gaps between the wafers in a stack”. It is obvious that the gap needs to be created between the uppermost wafer and the rest of the stack. One of the TRIZ Principles, “Pneumatics and Hydraulics”, offers an elegant solution of creating the gap by the compressed air jets. The application of this principle for our case study is described in [1] and the illustration of the proposed solution is shown in Fig. 4.

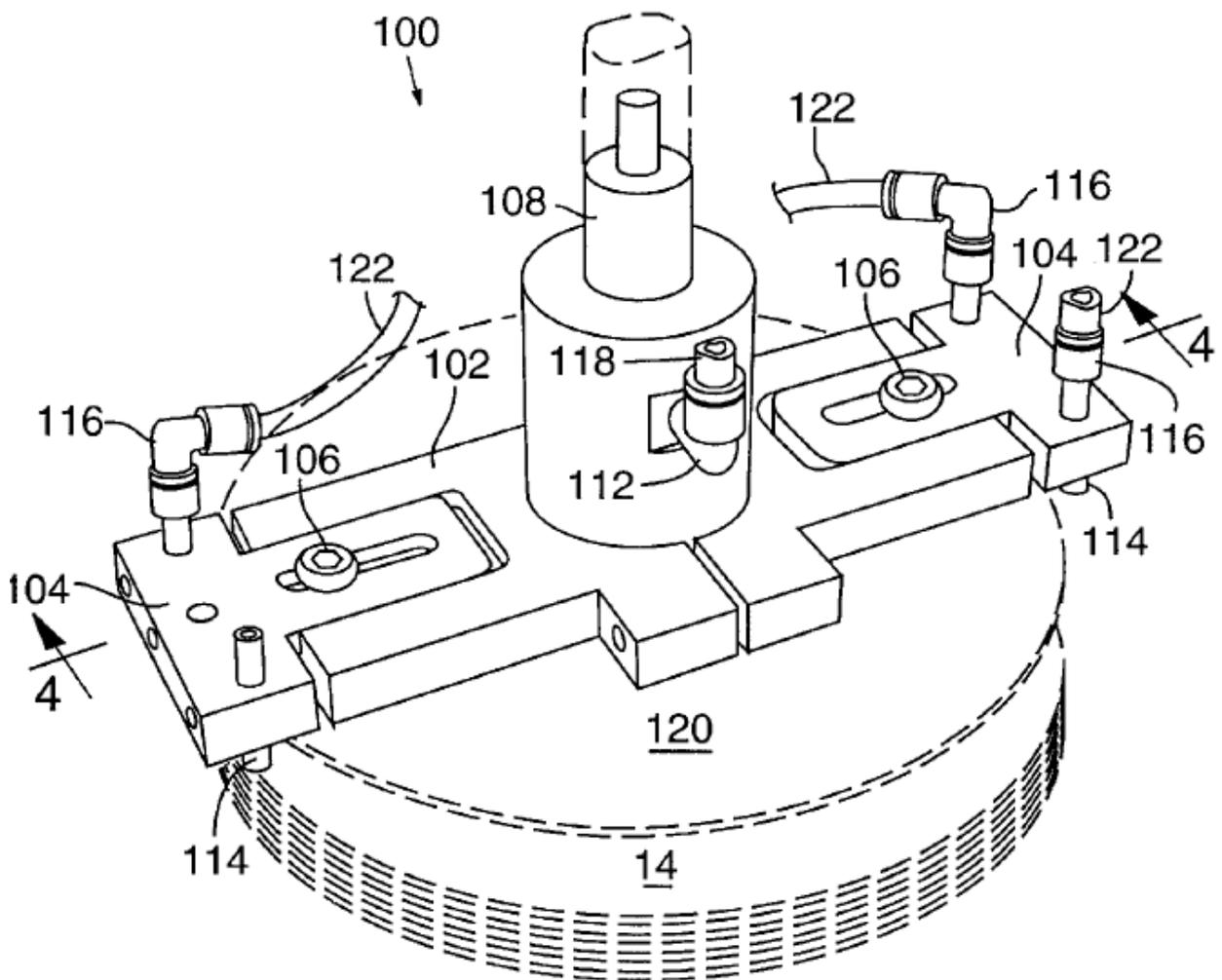
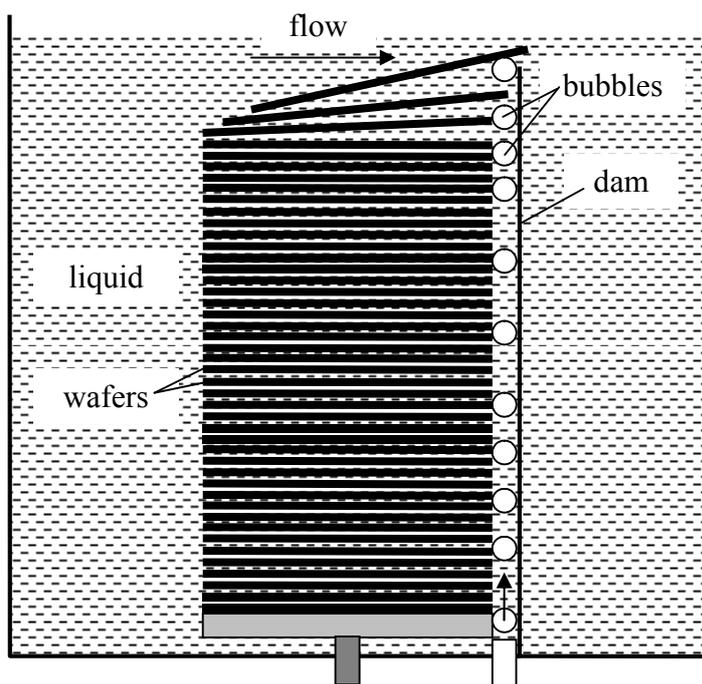


Fig. 4. Air Jet Separator. 114 – air nozzles, 116 – compressed air supply

This solution has been successfully implemented as a part of a larger wafer handling systems manufactured by Automation Technology, Inc, Salem, OR (US) – the assignee of the patent [1]. The same principle has been successfully used for separation of the paper sheets in the mailing machines, storage media such as CDs and DVDs in the label printing devices, and envelopes in the postal sorting machines.

### *Separation by Air Bubbles*

Air plays an important role in a very different separation concept based on the hydraulic separator (why-why diagram in Fig. 2). The why-why contradiction here is “how to eliminate the mechanical force applied to the wafer edge given that dam stops the rest of the wafers in a stack and water pushes them towards the dam?” This is a standard problem of eliminating a harmful action (or destroying a harmful su-field). According to the standard solution, a protection layer, preferably made



from the substances and fields already present in the operating zone, is to be applied between the dam and the wafers. An upward flow of air bubbles can be used as such protection layer (Fig. 5). In addition to protecting fragile edges from the impact by the dam, the bubbles can, actually, create gaps between the wafer edges and enable more reliable separation.

Fig. 5. Separation by Air Bubbles

## *Separation Without Spacers*

One of the contradictions resulting from the why-why diagram in Fig. 3 is

“how to maintain the spaces between the wafers without inserting spacers”.

The solution can be obtained by using Trimming: the function of a spacer can be transferred to the semiconductor material. This is done with a little help from the “Partial or Excessive Action” principle: a partial cut (say, 95%) of the semiconductor material leaving a common block holding the wafers together (Fig. 6). The vacuum wand attaches to the topmost wafer and the wafers are cut, one by one, off the common block. This way, the space between the wafers is maintained without the spacers.

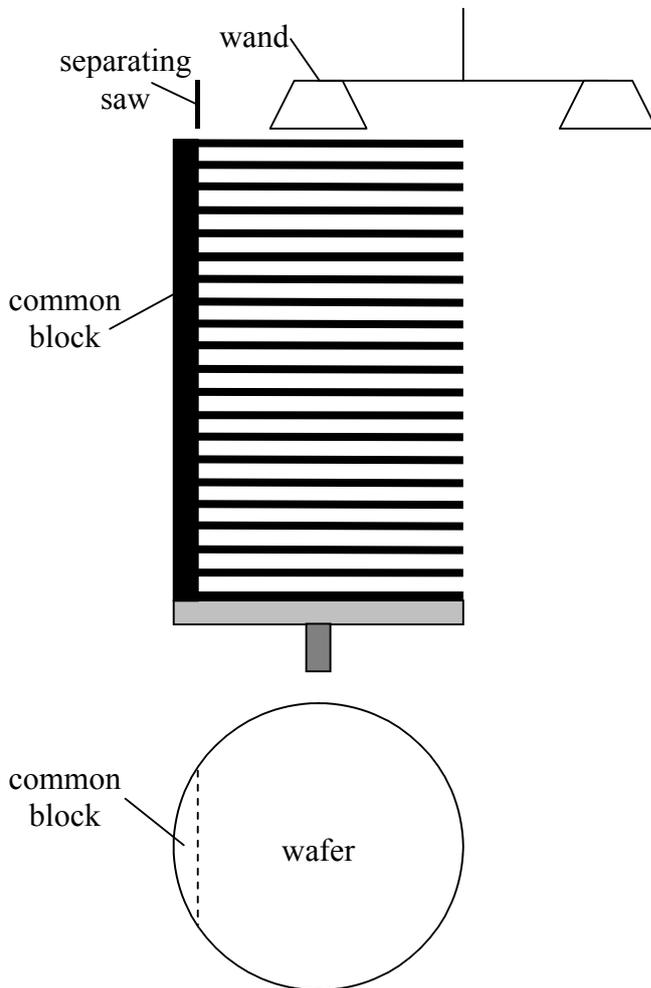


Fig. 6. Separation by Common Block

## **References**

1. US Pat. # 6,558,109.
2. Pinyayev A. M. A Method for Inventive Problem Analysis and Solution Based On Why-Why Analysis and Functional Clues. St. Petersburg, Russia, International TRIZ Association. TRIZ Master Thesis: 24 pp.
3. US Pat. # 5,213,451.
4. US Pat. # 7,637,713.