A method to measure Overall Material Efficiency in Semiconductor Backend Manufacturing Environment

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Abstract

The following paper introduces the Overall Material Efficiency (OME), a performance-measurement concept for material usage in semiconductor manufacturing. The OME breaks down the total material usage into main categories. The concept has proven useful to drive improvement in material management by highlighting areas for improvement, via tracking both the amount and cost of materials used in each category over time. The OME is also generic – the authors believe that the concept is relevant to all processes that involve production.

Keywords:
Overall Material Efficiency, material efficiency, material productivity, material losses

1. Introduction
In the semiconductor industry, the costs of production can be divided into personnel, capital and material costs. For backend manufacturing, there is a growing focus on managing material usage as it steadily becomes a big lever for cost reduction. This is especially so for large power semiconductor modules used for automobiles, photovoltaics and industrial drives. However, there seems to be an absence of an industry-wide standard governing or guiding material usage. This paper aims to fill in that gap by introducing the OME, forming a framework to classify material use and losses into logical categories. This clear identification of material losses can then be used to highlight areas for improvement, target setting and drive down material costs.
2. Research Methodology & Benchmarking
This project, while having some element of research requirements, is based mainly on the experience and benchmarking of industrial engineers, material planners, warehouse, purchasing, production and other stakeholders to design the measuring systematics. This project will facilitate the development of a common language for optimal leadership, strategy and organizational design to minimize wastages in the manufacturing process. This will benefit the company profit margin, consumed less resources, reduce wastages and/or carbon footprint.

3. Main Categories of Material Losses of Overall Material Efficiency
The main categories of Overall Material Efficiency are defined as the following:

1. Material due to Yield Loss, MYL refers to the physical material being in the product that is disposed due to bad yield or not meeting the final saleable form and standards (Non-Value Added, NVA Defect Waste).

2. Material Defect Loss, MDL refers to physical material that is disposed due to material defect from supplier source or material damage such as baseplate dented due to drop during handling or broken eggs in food industries (NVA Defect Waste).

3. Material Rework Loss, MRL refers to the additional physical material being consumed when the product is reworked due to customer return or internal reject such as cosmetic reject of the product (NVA Defect Waste).

4. Material Expiry Loss, MXL refers to physical material being in the product that is disposed due to time-limit expiry of material based on specification when the material is exposed to environment (manufacturing expiry or thawing expiry) and this also includes material that expired prior to application to the product. Material applied and subsequently scrapped due to material expiry violation at quality gate or inventory/warehouse storage also fall under this category. This will also lead to other wastes beside material (NVA Wastes such as: Transport, Inventory, Motion and Waiting).

5. Material Load-Factor Loss, MLL refers to the product from lot(s) cannot filled up the collection size such as entire lead-frame or tape. There is additional physical material being consumed or applied when the product is not available, such as: mold compound used on empty slot(s) at the lead-frame due to the lot size or incomplete reel due to the lot size. In cases where gases, vapor or liquid are used, this refer to the opportunities missed that the additional product can be processed during the same production run such as empty slots in cleaning or deposition machines. This will also lead to other wastes beside material (NVA Wastes such as: Transport, Inventory, Motion and Over-Processing).

6. Material Sampling Loss, MSL refers to the additional physical material being consumed when sampling is conducted for process or quality setup buy-offs (NVA Over-Processing Waste).

7. Material Initialization Loss, MIL refers to the material required to be consumed when the production begins like setup for process and/or quality specified buy-offs such as:
   a) Quantity of material required for dummy run
   b) Setup Lead-frames before production can commence
   c) Initial wire length pulled from new wire spool to the wire-bond machine in setup assuming one-time setup completed
   d) Mold Compound in the molding capillaries or run-offs.
   e) Mold Cleaning – planned (e.g. nikalet cleaning, rubber cleaning)
   f) Mold Cleaning – unplanned (e.g. machine stop >= 4hrs)

8. Material Efficiency Loss, MEL is difference between the plan and actual material usage factor. Example: Plan 1 shear test per lot. Instead of 1 piece but 3 pieces are used in the production. MEL = 3 – 1 = 2 pieces extra. It will be a negative value when there is a gain which is better than plan when measuring plan versus actual and vice-versa.
4. Application into Semiconductor Backend Manufacturing Environment

Based on the systematics defined, further sub-categories of different losses are further classified for various more refined sub-categories in a semiconductor backend manufacturing environment.

### Table 1: Sub-categories of Overall Material Efficiency

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<th>Level 1</th>
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<th>Level 3</th>
<th>Level 4</th>
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- **Non-Value-Add Loss - Unplan**
  - **Non-Value-Add Loss - Load Factor**
    - **Non-Value-Add Loss - Sampling**
      - **Material Sampling Loss**
        - MSLUP: Production Test (Extra Usage)
        - MSLUL: Setup for Engineering
      - **Material Sampling Loss**
        - MSLUP: Inspection Test Setup (Full Force/Shear/Wirebond)
        - MSLUL: Setup - Wafer Pass/Fail Setup
      - **Material Sampling Loss**
        - MSLUP: Test Wafer Setup (Full Force/Shear/Wirebond)
        - MSLUL: Setup - Wire Pass/Fail Setup
  - **Material Loss-Factor Loss**
    - **Material Loss-Factor Loss**
      - **Material Loss-Factor Loss**
        - MLLUP: Material Expired
        - MLLUL: Material Missing
      - **Material Loss-Factor Loss**
        - MLLUP: Inventory
        - MLLUL: Inventory Loss
      - **Material Loss-Factor Loss**
        - MLLUP: Overstock
        - MLLUL: Overproduction

- **Overhead Loss - Plan**
  - **Overhead Loss - Plan**
    - **Material Loss-Factor Loss**
      - **Material Loss-Factor Loss**
        - MILUP: Real Load
        - MILUL: Real Load
      - **Material Loss-Factor Loss**
        - MILUP: Real Load
        - MILUL: Real Load
  - **Overhead Loss - Unplan**

- **Value-Add**
  - **Value-Add**
    - **Overall Material Effectiveness**
      - OME: Overall Material Effectiveness
      - OMEVP: Normal Production
      - OMEVE: Engineering Lots for Sale
5. Conceptual Application of Overall Material Efficiency

5.1 Overall Material Efficiency Chart
In the idealistic scenario, the higher the proportion of OME, the higher the material efficiency as less material is wasted. With the Overall Material Efficiency mapped out correctly on materials used for manufacturing, productivity can target specifically on which area to focus for maximum gain.

An easier way to illustrate this will be represented through the Overall Material Efficiency Chart (see Figure 1 as an illustration of what is described):

![Overall Material Efficiency Chart](image)

Specific improvements must correlate to higher percentage (%) in terms of the OME. Clear and good trending both in terms of plan & actual can facilitate the Efficiency of productivity or areas of gaps.

By following the categories defined, meaningful comparison or trends can be created to:

- Look at trend of Actual Material Usage Factor
- Compare Plan Material Efficiency between different materials
- Compare Plan Material Usage Factor between different products
- Compare Plan versus Actual Material Usage Factor

5.2 Appropriate Axis
Overall Material Efficiency chart y-axis can be displayed to cater to different audiences:

- Absolute Numbers
  - Quantity
  - $ Value
  - Percentage (%)

- Normalized to per thousands
  - Quantity Per Thousand
  - $ Value Per Thousand

Overall Material Efficiency chart x-axis can be displayed in terms:

- Discrete Bar-chart based on
  - Material
  - Product
  - Plan
  - Actual
Continuous time buckets for trending purposes
  - Yearly
  - Quarterly
  - Monthly
  - Weekly
  - Daily

6. Real Application of Overall Material Efficiency
In the real application of OME, the main challenge is the availability of actual data. The relationship of how losses arise will also provide a fast approximation of standard losses incurred.

Many more useful comparisons can be derived to isolate which is the problematic area:

![Figure 2: Real Example of actual Overall Material Efficiency Charts](image-url)
7. Conclusion
The proposed measurement system using Overall Material Efficiency (OME) is still in the early stages. It has already triggered the stakeholders to have a thorough relook at the material usage in terms of both what they plan as target and what they actually consumed in the real production world. The next challenge will be how to enable consistent tracking of performance for regular review by key stakeholders.

The authors believe this measurement system will give rise to potential productivity opportunities such as those seen and experienced at the Overall Equipment Efficiency. This will also help to enable to reduce some of the 7 Wastes of Lean such as Defect, Transportation, Inventory, Motion and Over-Processing that incurred due to unprofitable activities carried out while handling material.

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References

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