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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.

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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 onetime 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 \geq 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.

9. Overall Material Efficiency, OME refers to the final amount of material shipped to customer which is considered as Value-Add.

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.

Level 1	Level 2	Level 3	Level 4	Level 5
	Non-Value-Add Loss - Unplan Non-Value-Add Loss - Load Factor	MYL: Material	MYLUP: Product Problem	MYLUPH: Hard bin
		Vield Loss		MYLUPM: Mechanical Flaw
		Held Loss	MYL RE: Product Problem	MYLREJ: Operation Scrap / Reject
		MDL: Material Defect Loss	MDL UP: Raw Material Physical Defect	MDL UPD: Damage / Chipped-Off
				MDL UPC: Crack
				MDL UPB: Bent
				MDL UPY: Warped Shape / Wrong Dimension
				MDL UPI: Indent
				MDL UPS: Scratch
				MDL UPM: Marking Off-Position
			MDL UV: Raw Material Visual Defect	MDL UVW: Discolouration / Watermark
			MDLUC: Raw Material Chemical Defect	MDL UCZ: Incorrect Chemical Composition / Shorted
				MDL UCO: Oxidation
				MDL UCQ: Corrosion
			MDLUE: Environmental Problem	MDL UET: Temperature
				MDL UEP: Pressure
				MDL UEH: Humidity
		MRL: Material Rework Loss	MRL UR: Rework	MRL URR: Rework for Customer Returns / Reject
		and a subsection of		MXLLIXO: Obsidiate Stock / No more demand
		MXL: Material Expiry Loss MLL: Material Load-Factor Loss	MXLUX: Material Expired MLLPL: Material & Product Lot Size Mismatched	MXLUXX: No WIP to run / Over-stock
				MXLUXE: Lack of Equipment to run
Non-Value- Add Loss				MULPIM: Oversized Material Lot (Material Lot > Product Lot)
				MIL PLP: Oversized Product for (Product for > Material for)
			MILL OL: Material & Product Lot Size Mismatched (Extra Usage)	will olivit (Extra wastage) oversized Material Lot (Material lot > Product lot)
		MLL: Material Load-Factor Loss	MLL UW: Material Waiting to be used	MLL UWW: Material is waiting at Warehouse
				MLL UWP: Material is waiting at Production Area
				MLL UWM: Material is waiting at Machine
				MLL UWX: Material is waiting at Unknown Location
	Non-Value-Add Loss - Sampling	MSL: Material Sampling Loss MSL: Material Sampling Loss	MSL US: Production Test (Extra Usage)	MSLUSP: (Extra Usage) Setup - Scheduled Test (Pull Force/Shear/Wirebond)
				MSLUPS: (Extra Usage) Setup - after Scheduled Down
			MSL US: Setup for Engineering	MSLUSE: (Extra Usage) Setup - Engineering Use (Experiments, Unsellable Samples)
			MSL US: Setup (Extra Usage)	MSLUSC: (Extra Usage) Setup - Change/ Conversion
				MSLUSM: (Extra Usage) Setup - Clean Mold
				MSLUSW: (Extra Usage) Setup - Waxing
				IVISLIUSI: (Extra Usage) Setup - Test Shot
				INSLUED: Setup - after Unscheduled Down
				MSLUSZ: Setup - due to Mord Waiting
				MSL DXW: Setup - Wire Breakage / Wire Re-Setup
			MSL PP: Production Test based on Spec	MSLPP1: Setup - Scheduled Test (Pun Porce/Snear/Wirebond)
				WSLPPS: Setup - after Scheduled Down
			MSLPS: Setup for Engineering	IVISLPSE: Setup - Engineering Use (Experiments, Unsellable Samples)
			MSLPS: Setup based on Spec	MSLPSC: Setup - Change/ Conversion
				MSLPSM: Setup - Clean Molo
				WSLPSW: Setup - Waxing
				MULPSI: Setup - rest shot
	Overhead Loss - Plan	MIL: Material Initialisation Loss	MILPD: Discontinuation	MIL PDL: Reel leader
				MIL PDJ. Reel Joint Loss
				MIL PDT. Reel Trailer
				MILPDI: Reel trailer
Overhead Loss				MILLIDIA (Estas Usasa) Badilas das
	Overhead Loss - Unplan		MIL UD: Discontinuation (Extra Usage)	MILLODI: (Extra Usage) Reel leader
				MILLIDI: (Extra Usage) Reel Joint Loss
				MILLIDT: (Extra Usage) Reel Trailer
		MEL: Material Efficiency Loss	MELLIV, Variance	MELUNC: Supplied Ougetity Veringen
				Microvs. Supplied Quantity variance
			MELUA: Adjustment	IVIEL UAV: VIRtual Stock Adjustment / Key In Error
			MEL UU: Unknown Unplanned Extra Usage (Gain/Loss)	MELUUM: Miscellaneous for all undefined/other cause(s)
Value-Add	Value - Add Usage	OME: Overall Material	OME VP: Normal Production	OME VPN: New Fresh Material for Production
				OME VPR: Recycled Material for Production
		Effectiveness	OME VE: Engineering Lots for Sale	OME VES: Material used for Sellable Samples (eg. Prototypes)

Table 1: Sub-categories of Overall Material Efficiency

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):



Figure 1: Conceptual Example of Overall Material Efficiency Chart

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
 - o \$Value
 - o 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
 - \circ Product
 - o Plan
 - o Actual

- Continuous time buckets for trending purposes
 - Yearly
 - Quarterly
 - Monthly
 - Weekly
 - o 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

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7. Conclusion

The proposed measurement system using Overall Material Efficiency (OME) is still in the early stages. It has already trigger 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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Biographies

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