

# Wafer Defect Analysis Report

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## Executive Summary

This report summarizes the analysis of wafer inspection data from a semiconductor manufacturing process. We cleaned and prepared data for 25,000+ wafer inspections, then examined key quality metrics. Our findings highlight:

- An overall failure rate of **41.9%** and average defects of **2.95 per wafer**
- A monthly failure rate stable around **42%**, with a peak of **44%** in July 2024 and a dip to **40%** in May 2025
- Tools **DUV-2100** and **ETCH-V9** showing the highest failure rates (43% and 42%) and defect counts
- Batches **BAT022**, **BAT004**, and **BAT008** having the worst performance (44% failure)
- **Particle contamination** and **overlay misalignment** as the top defect types, accounting for **62%** of all failures

Recommendations include focusing on contamination control, tool maintenance for DUV-2100, and root cause analysis for high-failure batches.

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## 1. Introduction

Semiconductor wafers undergo multiple process steps that can introduce defects. Monitoring wafer quality is critical to yield and customer satisfaction. This project uses a simulated but realistic dataset to demonstrate how a data analyst would: 1) clean raw inspection data, 2) calculate quality metrics, and 3) build a clear dashboard with actionable insights.

**Project Goal:** Provide a snapshot of wafer quality and identify the main areas for process improvement in a semiconductor fab.

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## 2. Data & Methodology

### 2.1 Data Description

- **Source:** Simulated wafer inspection records (25,000+ rows)
- **Key columns:** wafer\_id, batch\_id, tool\_id, defect\_type, defect\_count, inspection\_result (Pass/Fail), inspection\_date

### 2.2 Data Cleaning Highlights

- Removed or flagged rows with missing wafer IDs, tool IDs, defect counts, and dates
- Corrected logical errors: 113 rows with no defect but marked Fail were set to Pass with defect\_count = 0
- Excluded outliers: defect counts above 50 were flagged and removed from analysis
- Excluded rows with invalid dates (error\_date)
- Ensured no duplicate rows remained

A final cleaned\_data sheet contains only valid, analysis-ready records.

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## 3. Key Performance Indicators (KPIs)

Metric	Value
Total Inspections	24,697
Pass Rate	58.1%
Fail Rate	41.9%
Average Defect Count per Wafer	2.95
Max Defect Count (Sanity)	50
Top Defect Type	Particle contamination (4,999)

These KPIs provide a quick overview of overall process quality.

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## 4. Monthly Trend Analysis

A line chart of monthly failure rates shows:

- **July 2024:** Highest failure rate at 44%
- **May 2025:** Lowest failure rate at 40%
- Overall trend stable around 42%

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## 5. Tool Performance

### 5.1 Failure Rate by Tool

Tool ID	Failure Rate
DUV-2100	43.0%
ETCH-V9	42.0%
CVD-Z5	42.0%
CMP-X7	41.9%
EUV-3000	41.0%

*DUV-2100* shows the highest failure rate and should be reviewed for calibration and maintenance.

### 5.2 Average Defects by Tool

Tool ID	Avg Defects
DUV-2100	3.00
ETCH-V9	2.98
CVD-Z5	2.95
CMP-X7	2.91
EUV-3000	2.88

High defect counts on *DUV-2100* and *ETCH-V9* align with their failure rates.

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## 6. Batch Performance

Top 10 batches by failure rate:

Batch ID	Failures	Passes	Failure Rate
BAT022	352	440	44.0%
BAT004	339	425	44.0%
BAT008	350	442	44.0%
BAT012	369	470	44.0%
BAT006	362	467	44.0%
BAT011	353	464	43.0%

BAT015	344	455	43.0%
BAT007	349	462	43.0%
BAT017	350	464	43.0%
BAT010	351	467	43.0%

These batches may have had local process issues or material variability and warrant further root cause analysis.

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## 7. Defect Type Analysis

Defect Type	Fail Count
Particle contamination	3,825
Overlay misalignment	2,873
Etch residue	1,497
Scratches	1,230
Photoresist peeling	922

Particle contamination and overlay misalignment account for nearly 62% of all failures, indicating a strong need to improve cleanroom controls and overlay accuracy.

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## 8. Business Recommendations

1. **Contamination Control:** Enhance cleanroom protocols and filter maintenance to reduce particle contamination.
2. **Tool Maintenance:** Schedule detailed calibration and preventive maintenance for DUV-2100 and ETCH-V9.
3. **Batch Process Review:** Investigate high-failure batches (e.g., BAT022) for process deviations, material lots, or operator practices.
4. **Alignment Procedures:** Review overlay alignment procedures and tool settings to lower misalignment defects.

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## Appendix

- Detailed cleaning log and intermediate flag columns are available in the `Cleaning_Log` sheet.
- All PivotTables and charts used for analysis are on separate sheets for transparency.