Semiconductor Foundry Verification

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In collaboration with Sandia, DOJ and CMU/ECE

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DM-0004084

Foundation and Collaboration

Collaboration:

- Sandia – counterfeit microcontroller detection
- CMU/ECE – Foundry information, samples of various manufacturing processes
- DOJ – Counterfeit microcontroller samples

Foundation:

- Research project based on SEI's previous research related to microcontroller algorithms detection and recovery
- SEI's extensive experience in code analysis and anomaly detection

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Problem Statement

Chips delivered are not the chips requested

- Different layout, process, materials, components, tolerances, etc.

May or may not do everything the original chip does

- May or may not do extra, potentially undesirable things as well

Most chips in consumer devices not made in U.S.

- Introduces supply chain issues
- Subcontractor of subcontractor of subcontractor of …

Chip markings and packaging often similar/identical

- Need deeper analysis

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Research Objectives

Semi-automated image processing to identify semiconductor foundry

- Each layer is photographed and processed
- Relevant features extracted and checked against rules

Fabrication facilities have design and fabrication requirements and tolerances

Some potential examples:

- No acute angles or angles of non-45 degree integer multiples
- All metal feature sizes must be multiples of X nm
- Metal layers will be copper

Failure to meet these rules flags chips as potential counterfeits

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Integrated Circuit Fabrication

Doping agents, glasses, or metals on silicon

- Individual components nowadays are on the order of 100nm~10nm

Chips are multi-layered

- Bottom layer is transistors, other silicon features
- Layers above alternate:
  - Metal interconnects (copper/aluminum)
  - Vias (same material as metal)
  - Glass (Silicon Dioxide) between all of this, isolating the layers
- Topmost layer contains pads for connecting to packaging and an encapsulation layer

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Integrated Circuit Delayering

Chemical processing to strip individual layers off

- Basically controlled dissolving of glass and metal

Primary chemicals:

- Copper/aluminum etchant (depending on IC metal layer)
- Hydrofluoric acid (for dissolving glass)
- Phosphoric acid (for dissolving encapsulation layer)

Dissolving each layer requires two or three steps (depending on layer)

Layers imaged with optical microscopy camera at each layer

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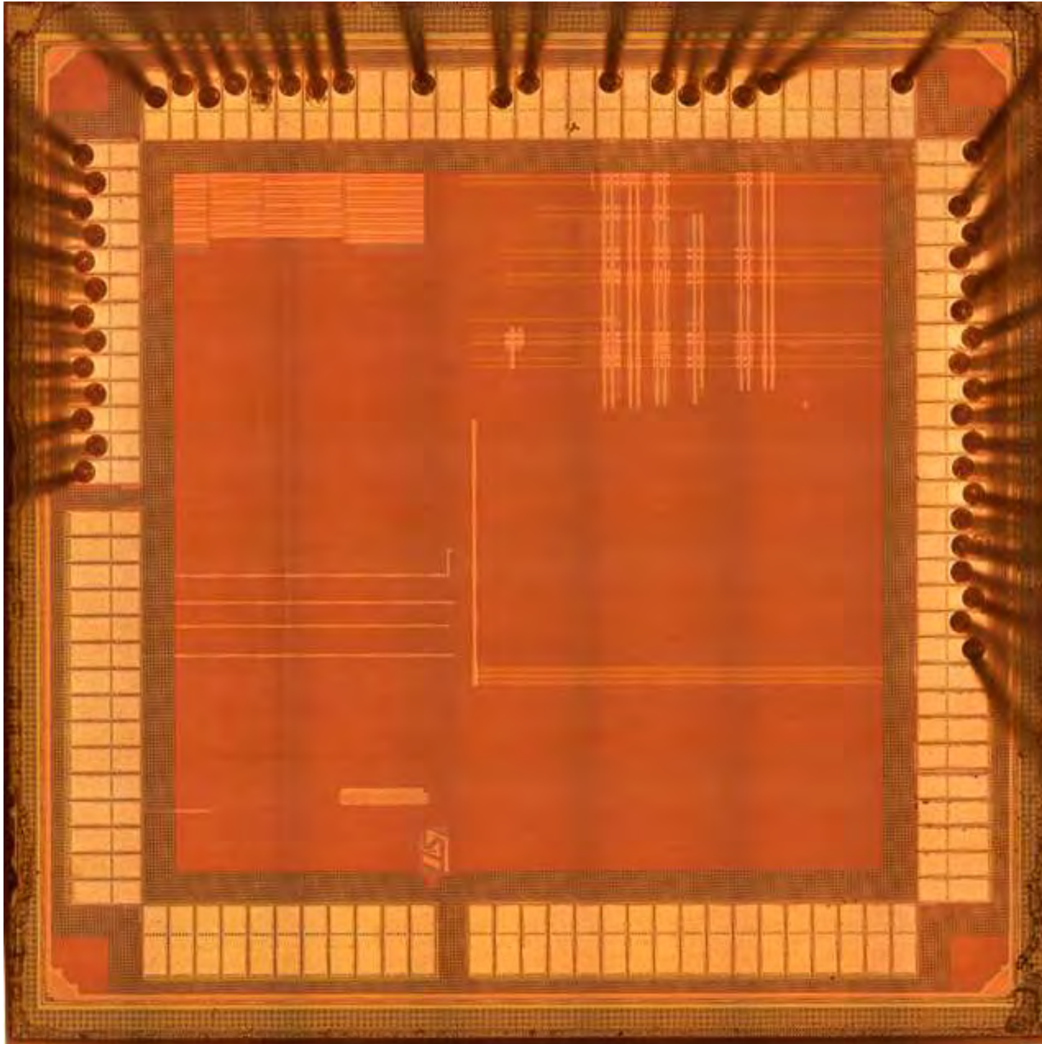
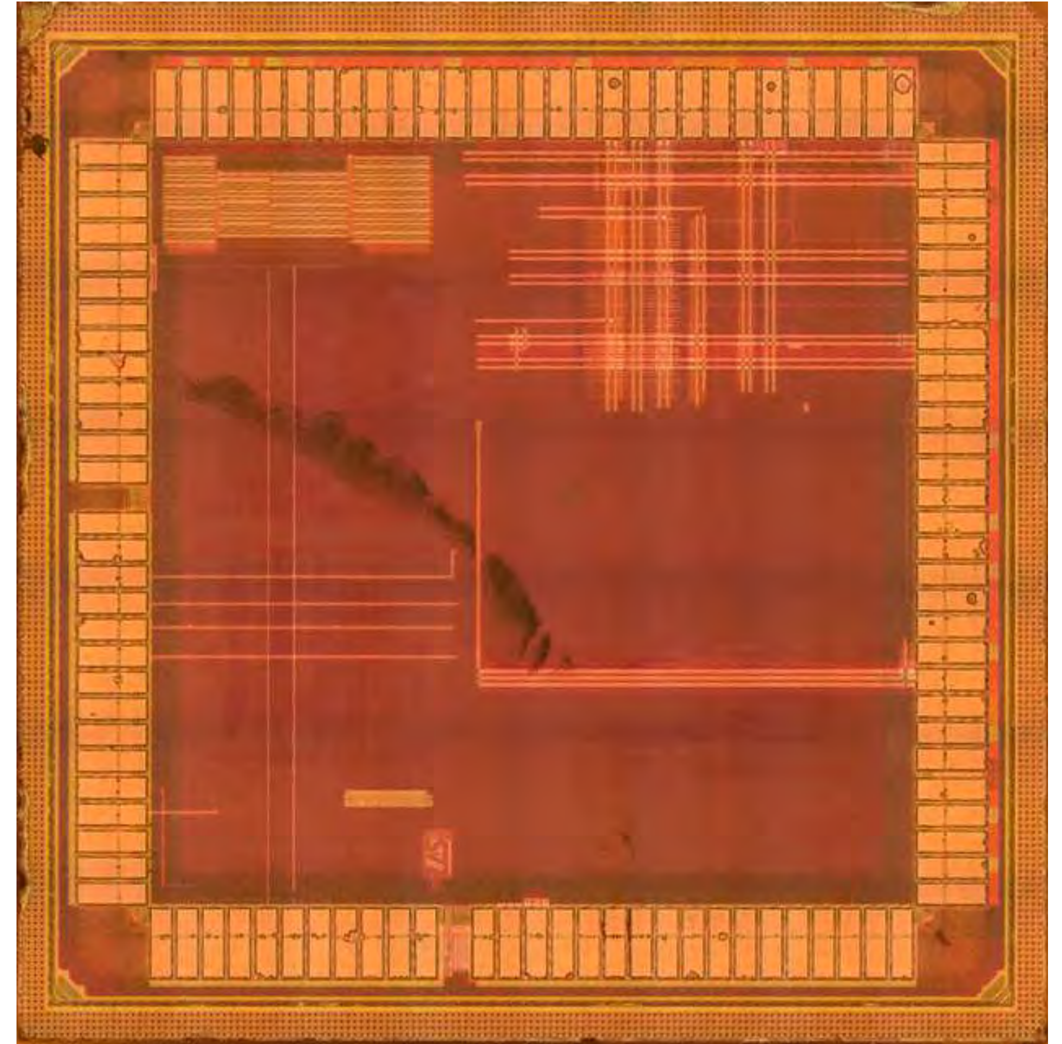
Pre-etch, 40x (scaled down resolution)



Encapsulation and glass etched, 40x (scaled down resolution)



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Pre-etch, 40x (scaled down resolution)

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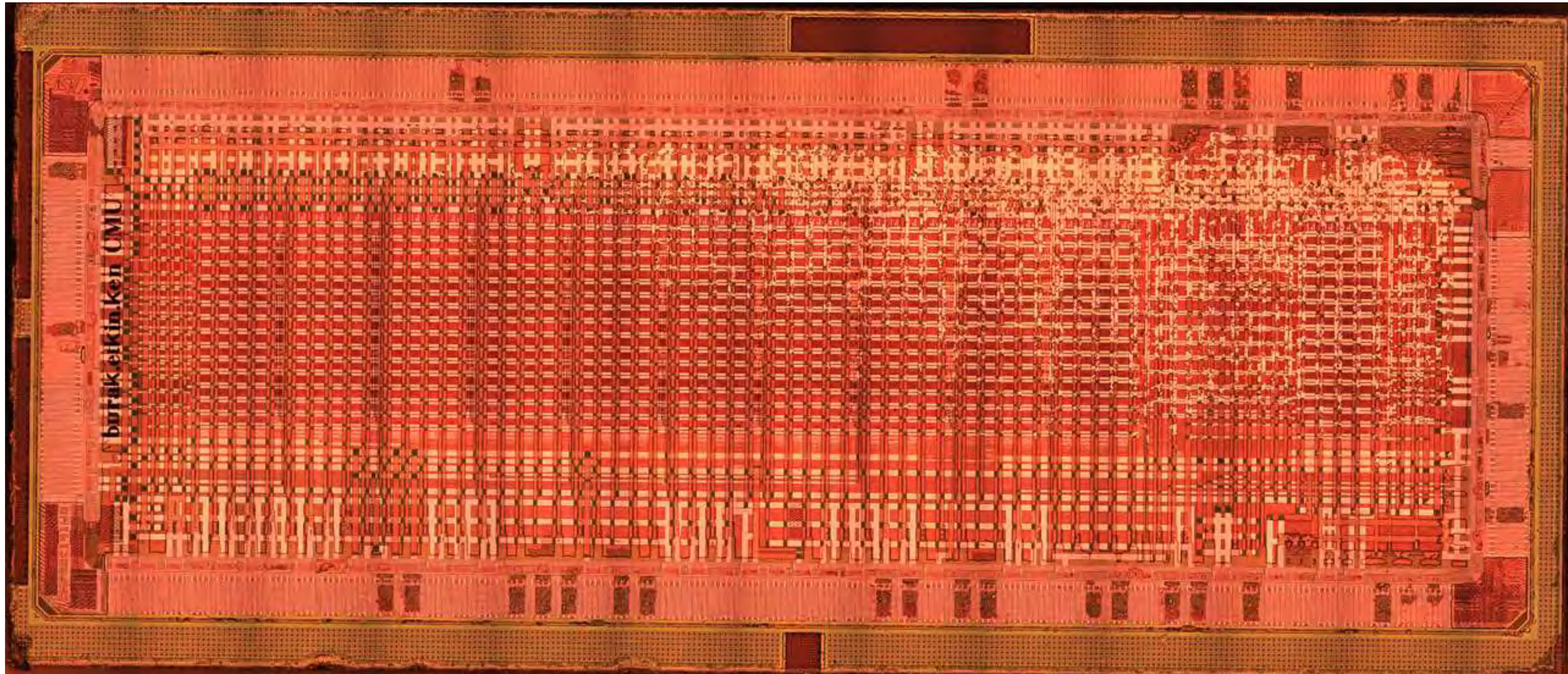
Top metal layer removed, 40x (scaled down resolution)



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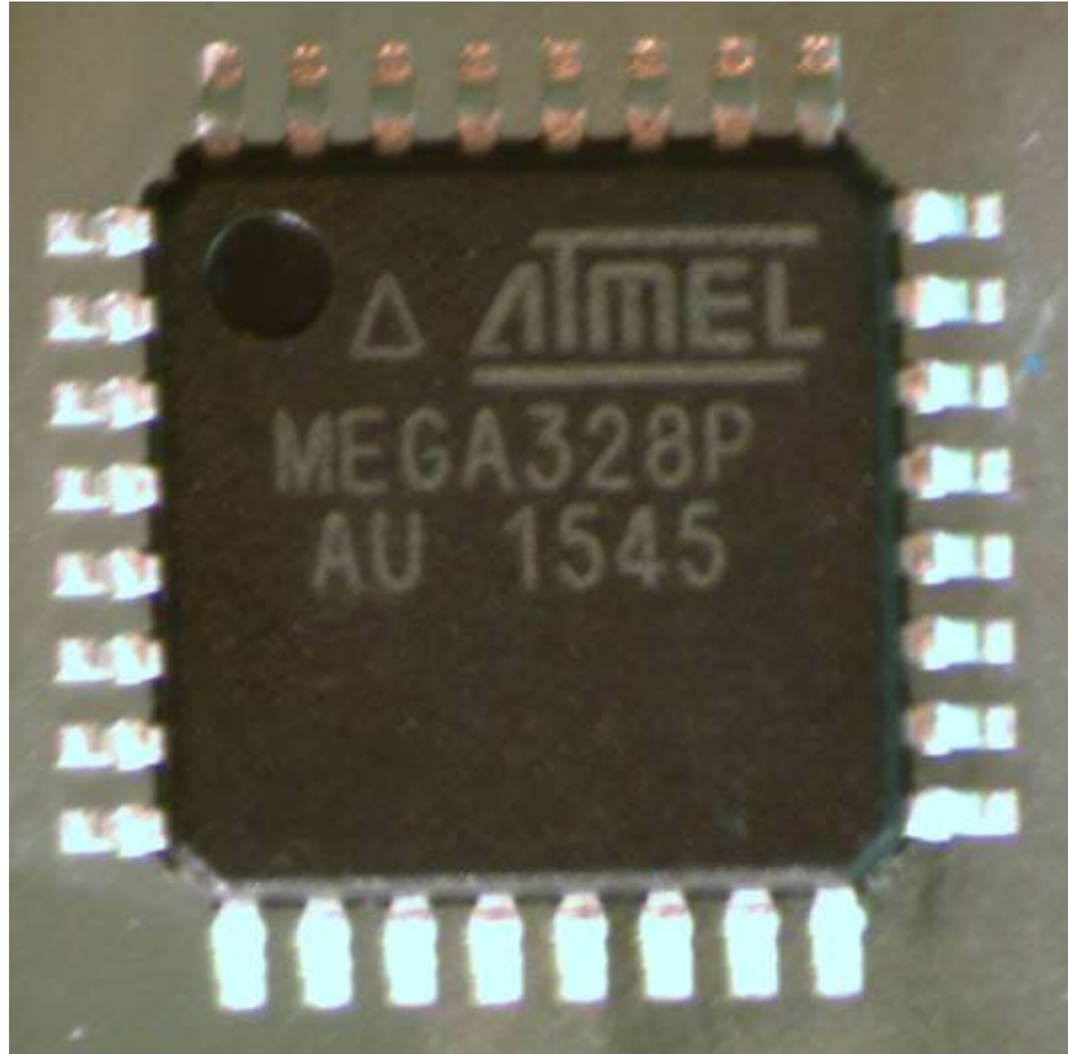
Counterfeit Examples



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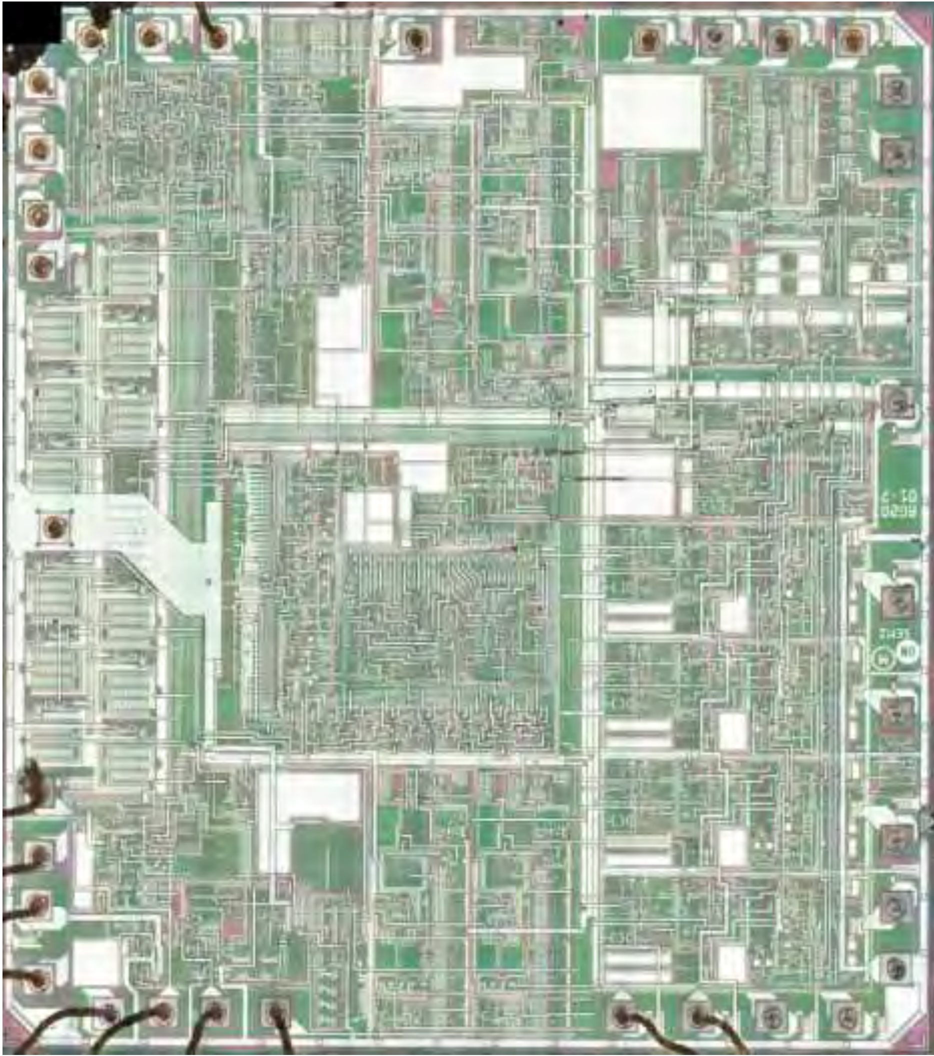
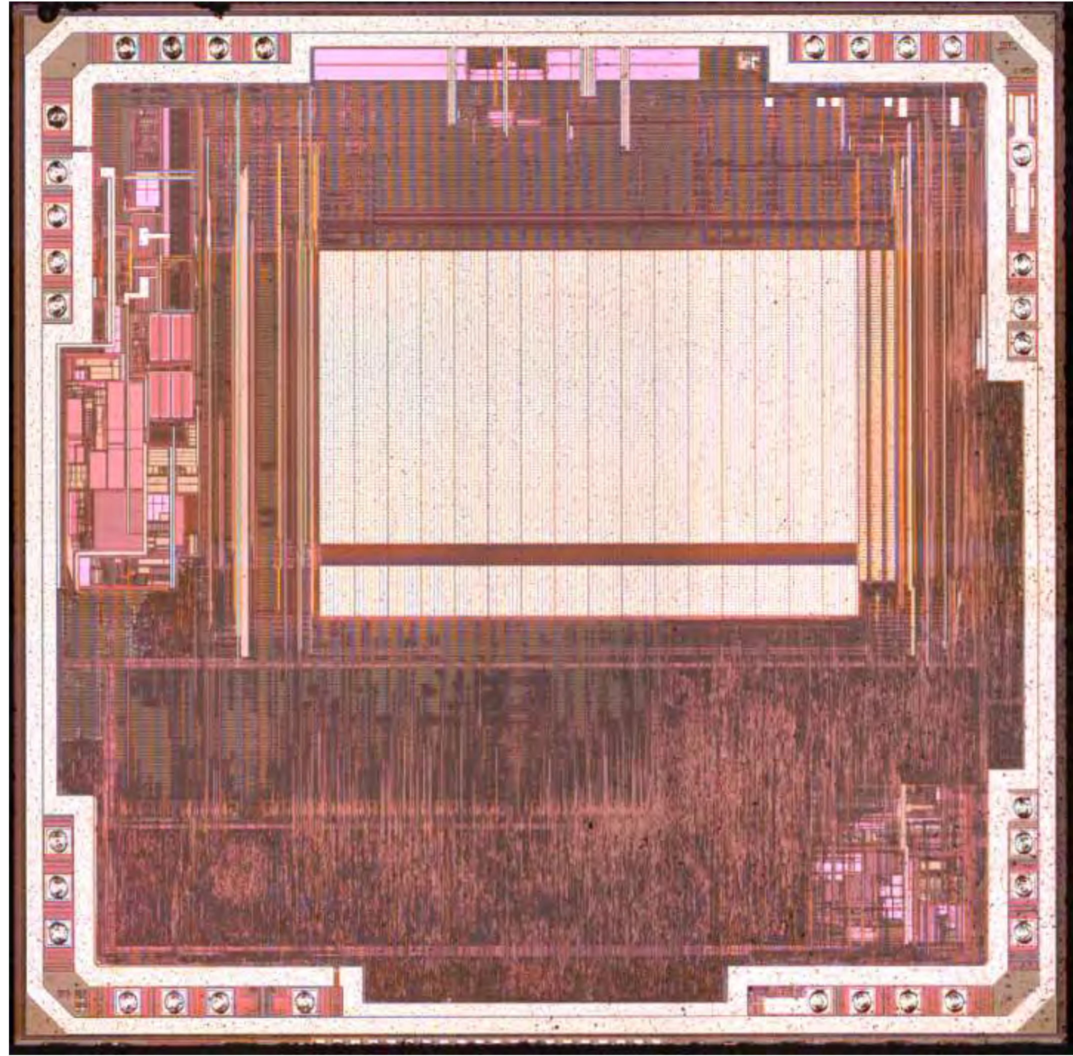
Decapping and Visual Analysis





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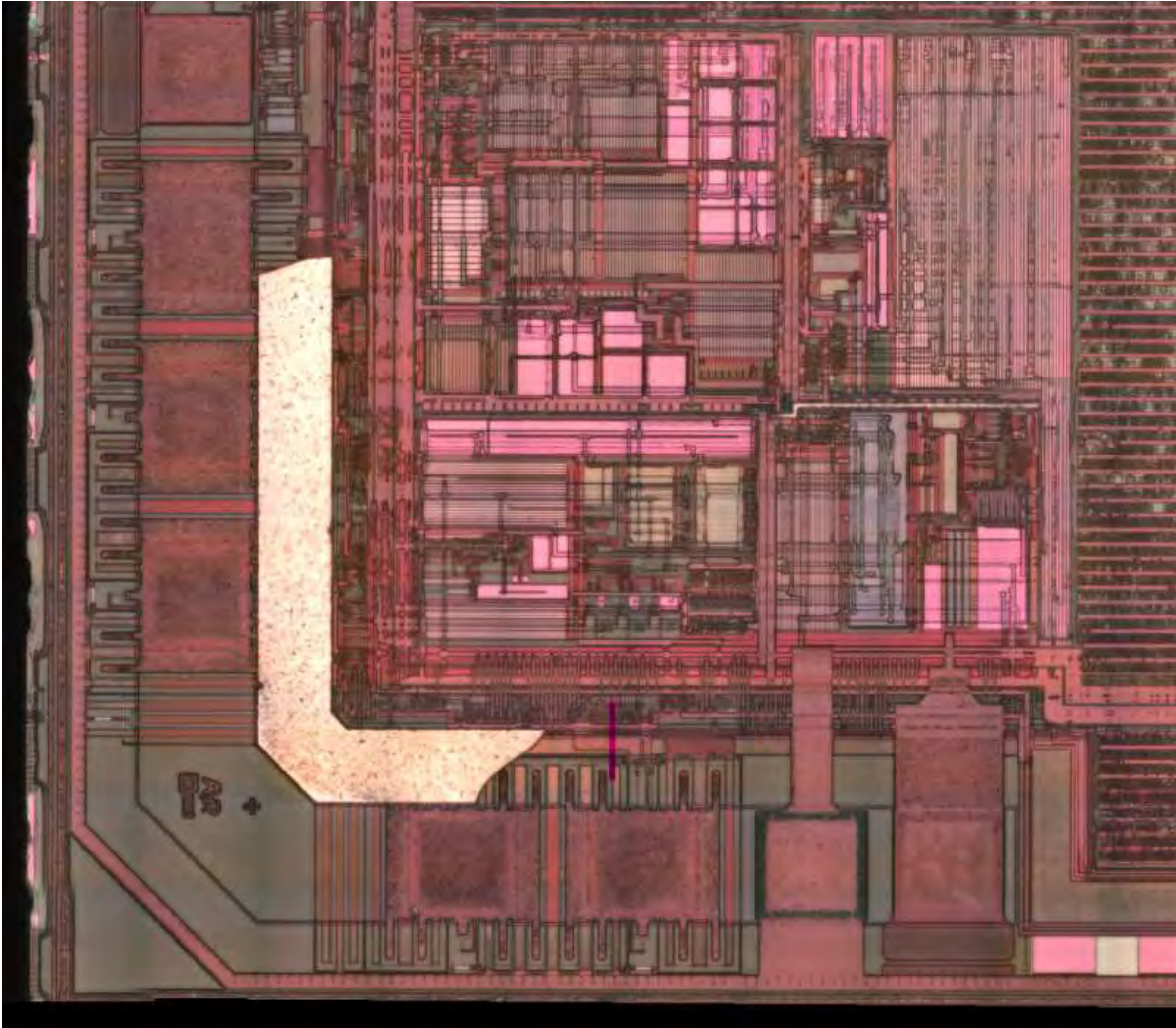
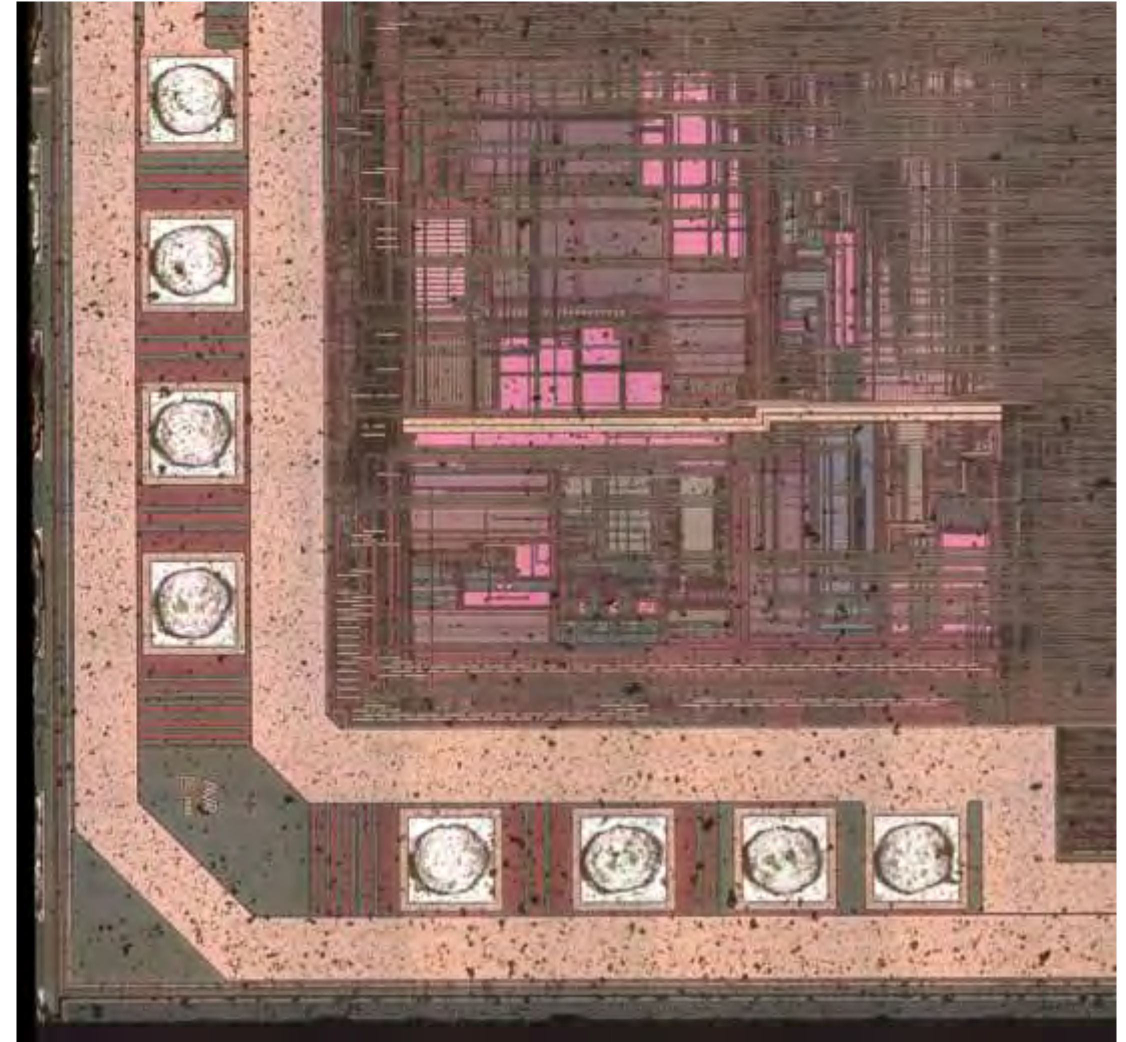
Features at Different Layers





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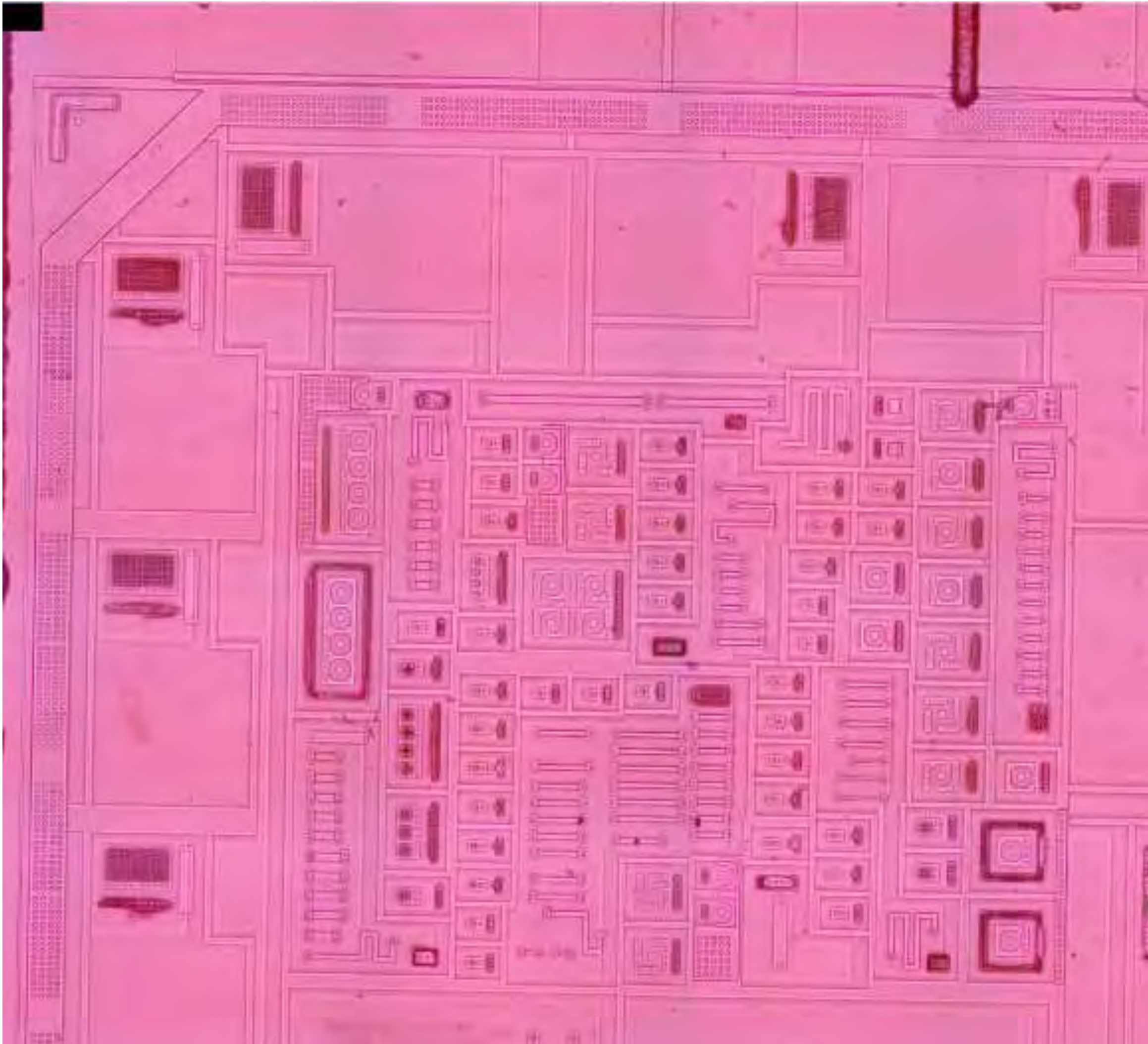
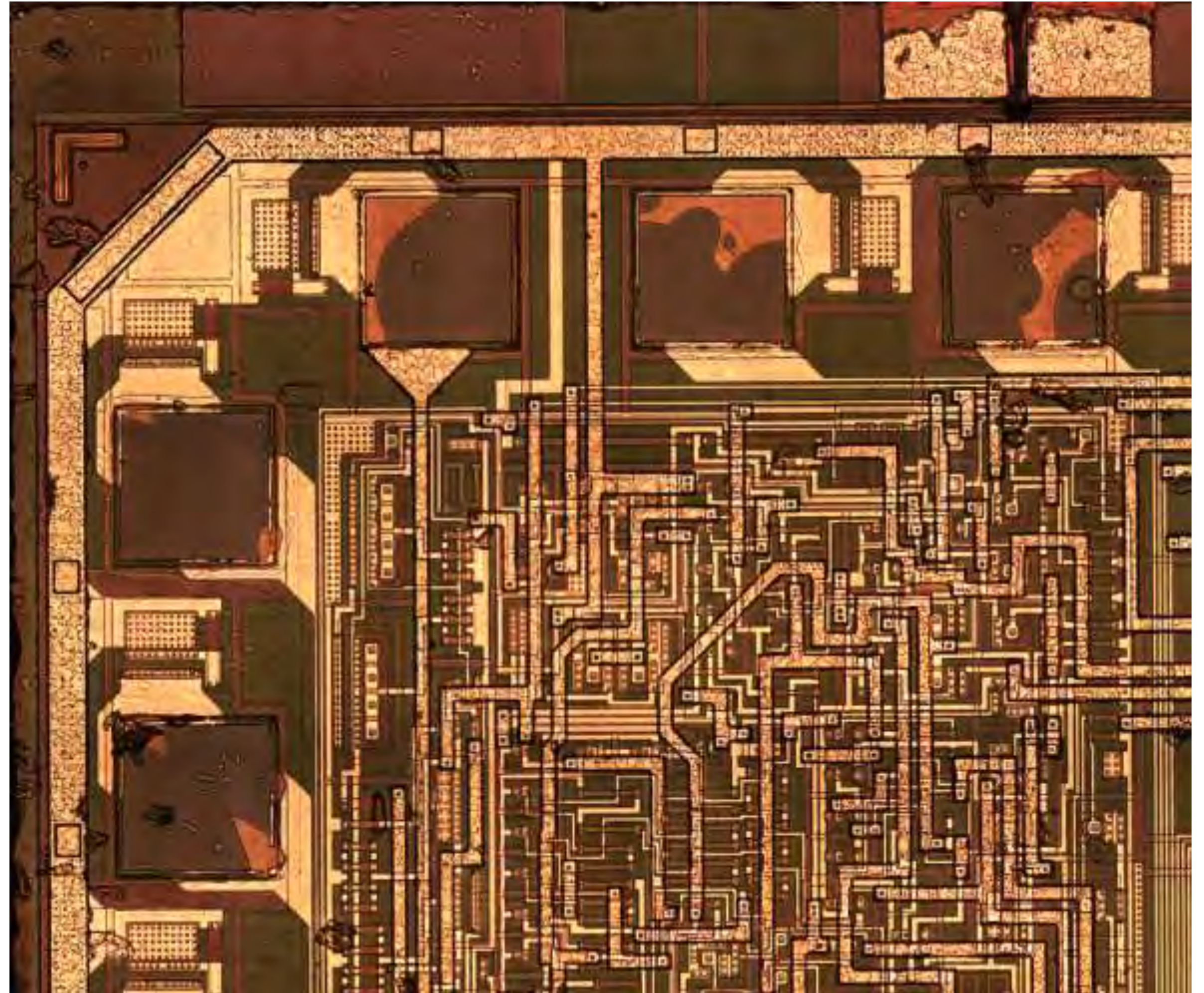
Counterfeit Chip at Different Layers





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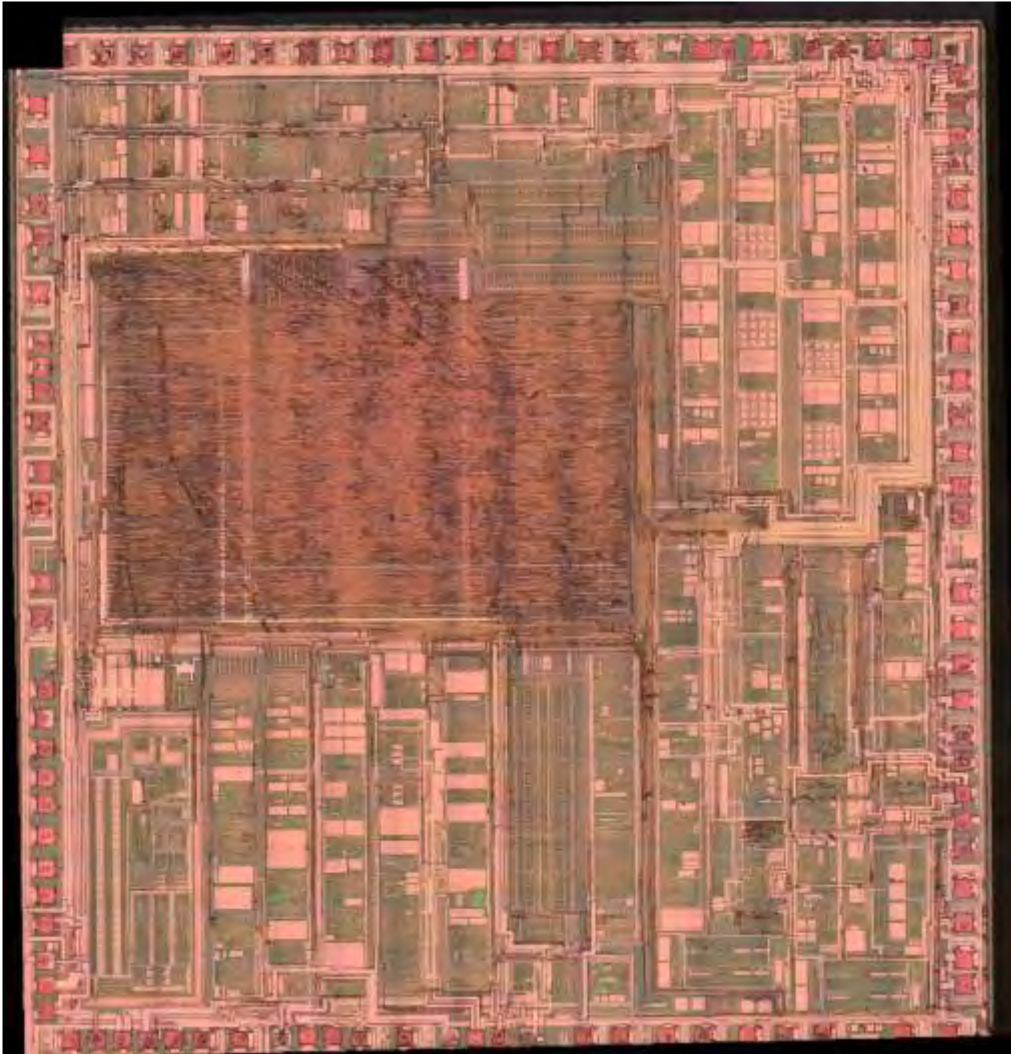
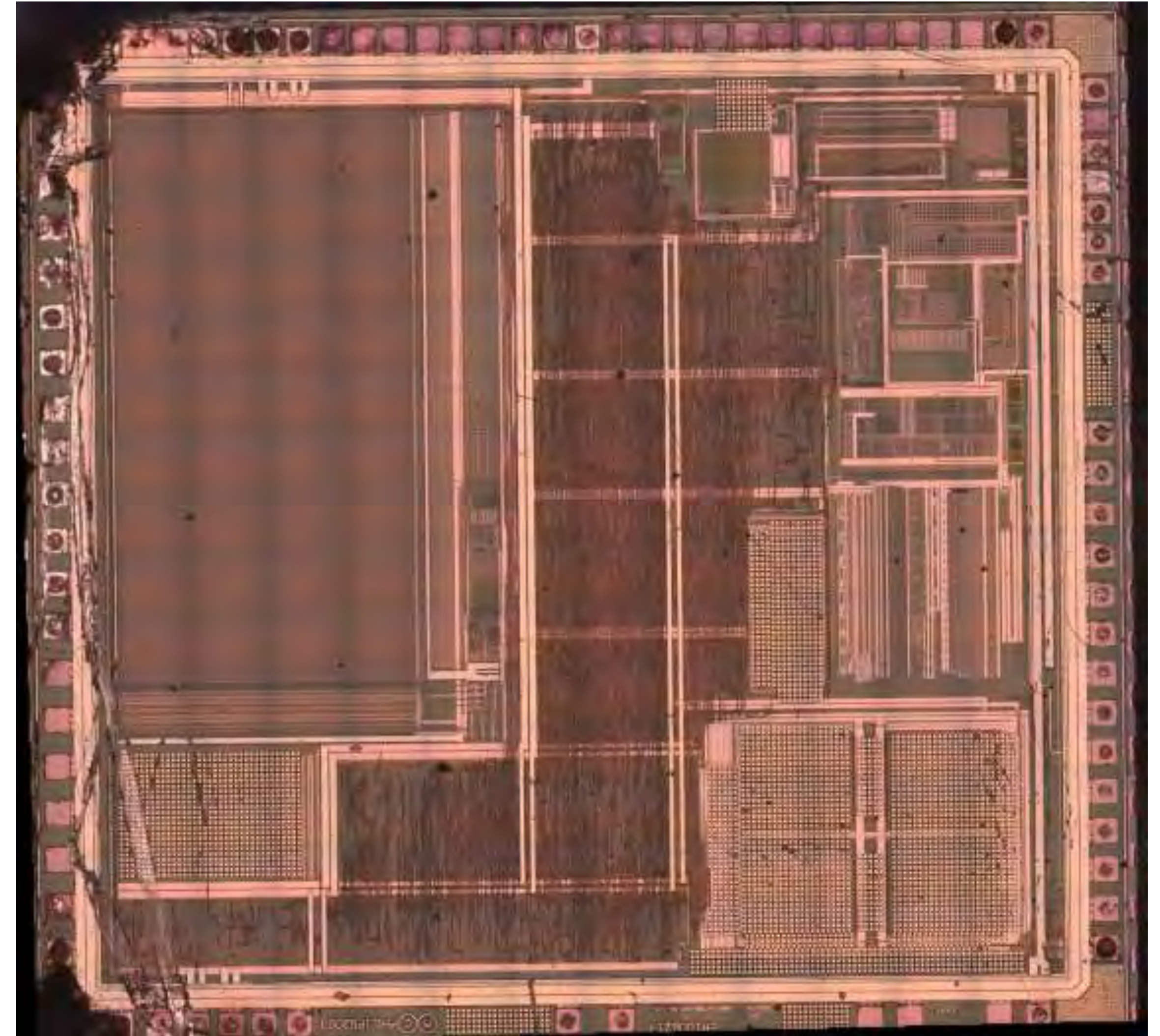
Differences in Fabrication





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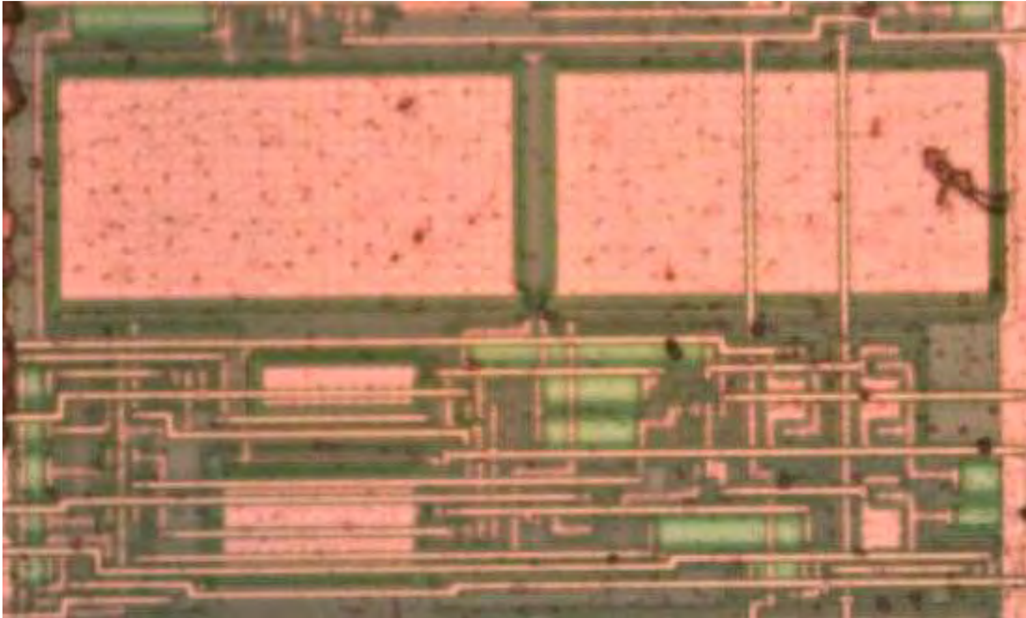
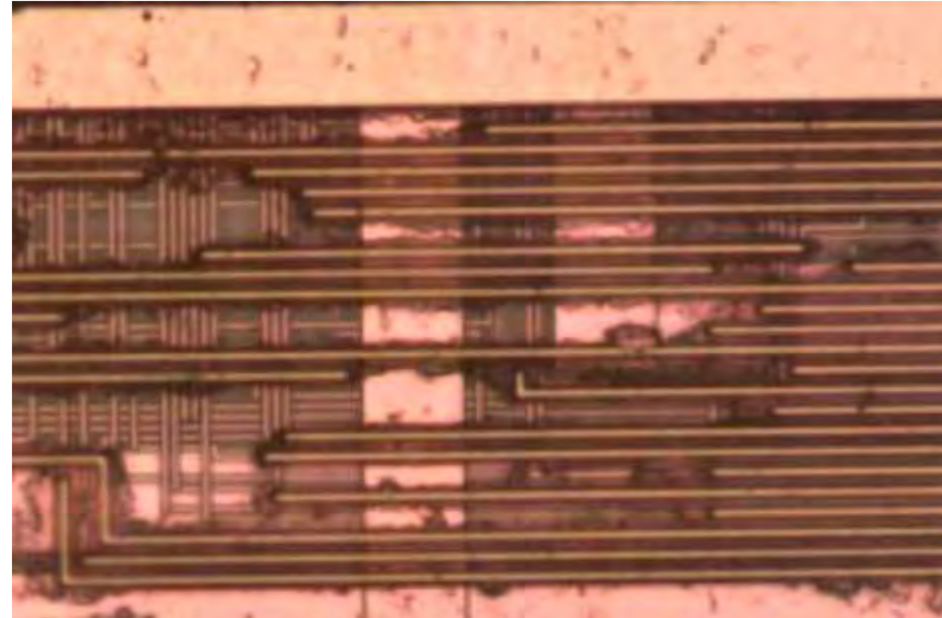
Same Foundry





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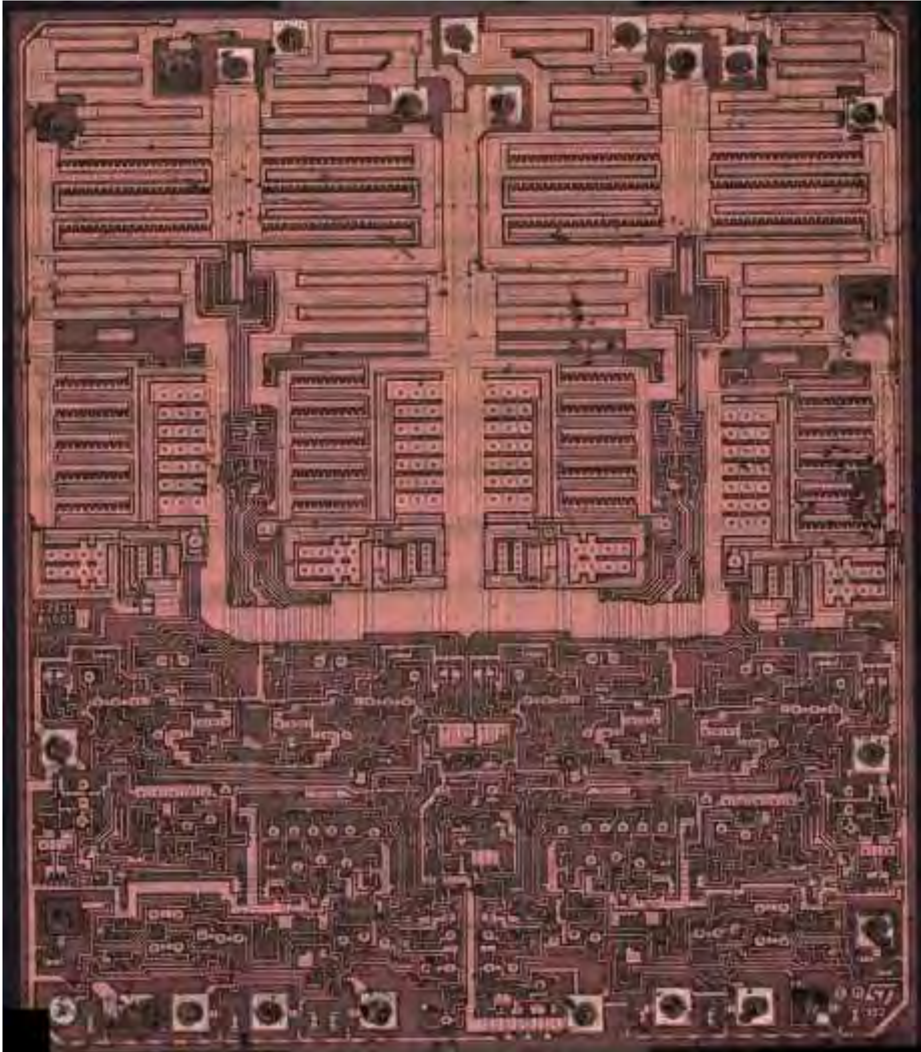
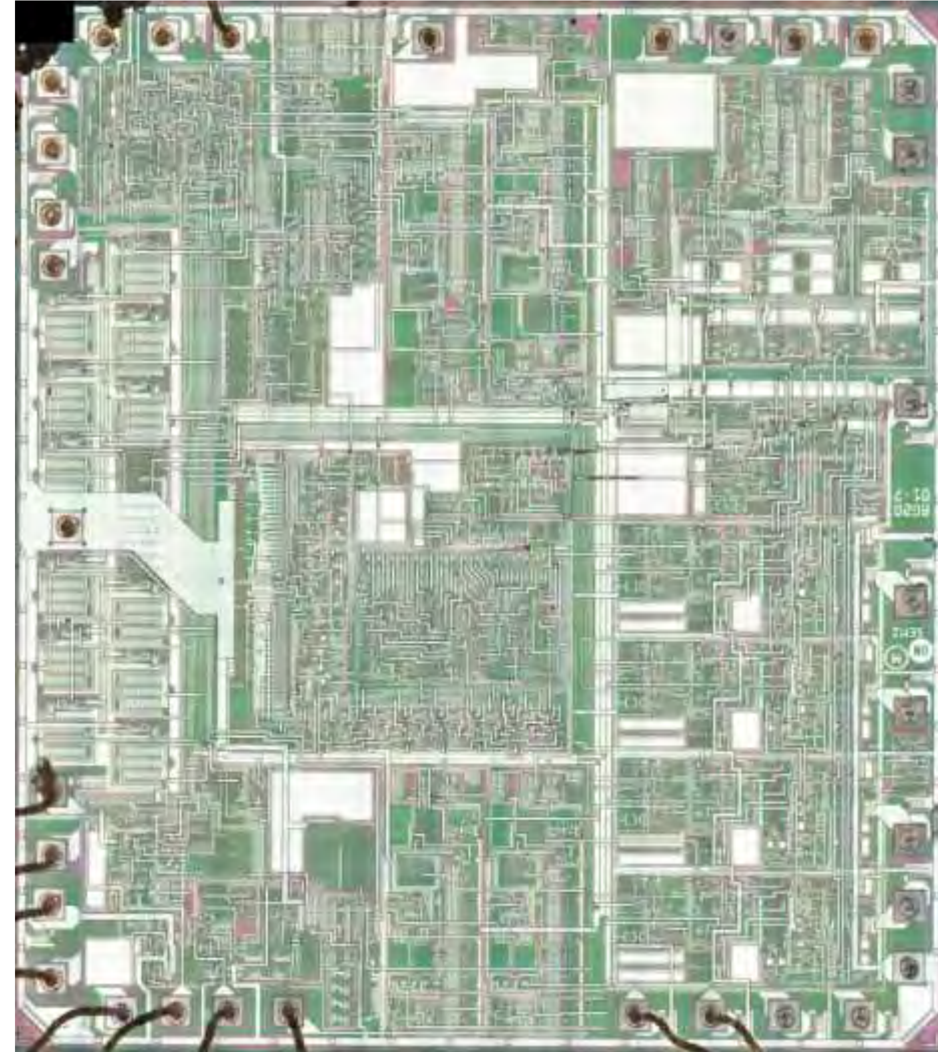
Different Foundries





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Different Foundries

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Other Deliverables: Automated Analysis Methods and Results

- DBScan_points.py is a program used in FIJI to gather the points in a readable format for other programs that perform cluster analysis.
- DBScan.py performs the density based spatial cluster analysis with noise.
- PDBScan_convert.py is a program to convert the point set to another format for a different program to read and perform parallel cluster analysis.
- SelectPoints.py is a program to take the points of a cluster and select them as multi point selection ROI in FIJI
- 3D_DBScan_points.py gathers the points in a readable format for the 3D_DBScan.py program.
- 3D_DBScan.py performs DBScan on RGB coordinates in an image.
- Color_on_image.py takes the found clusters and colors the image accordingly in FIJI.

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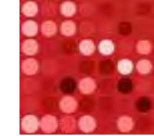
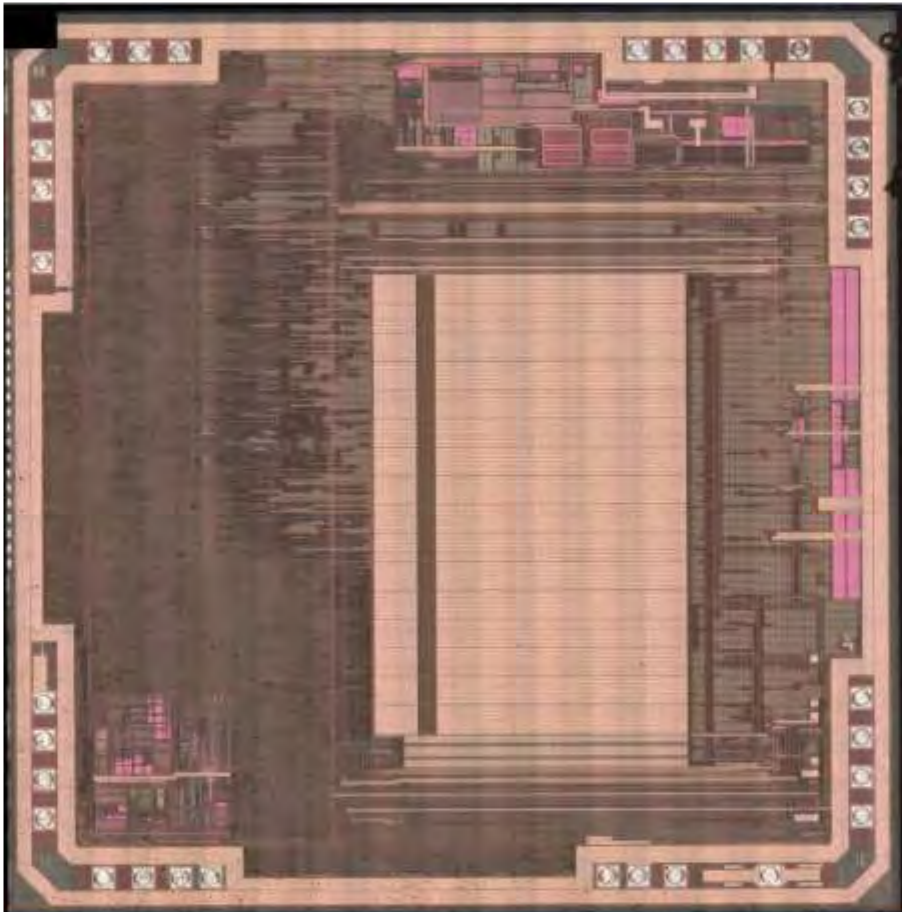
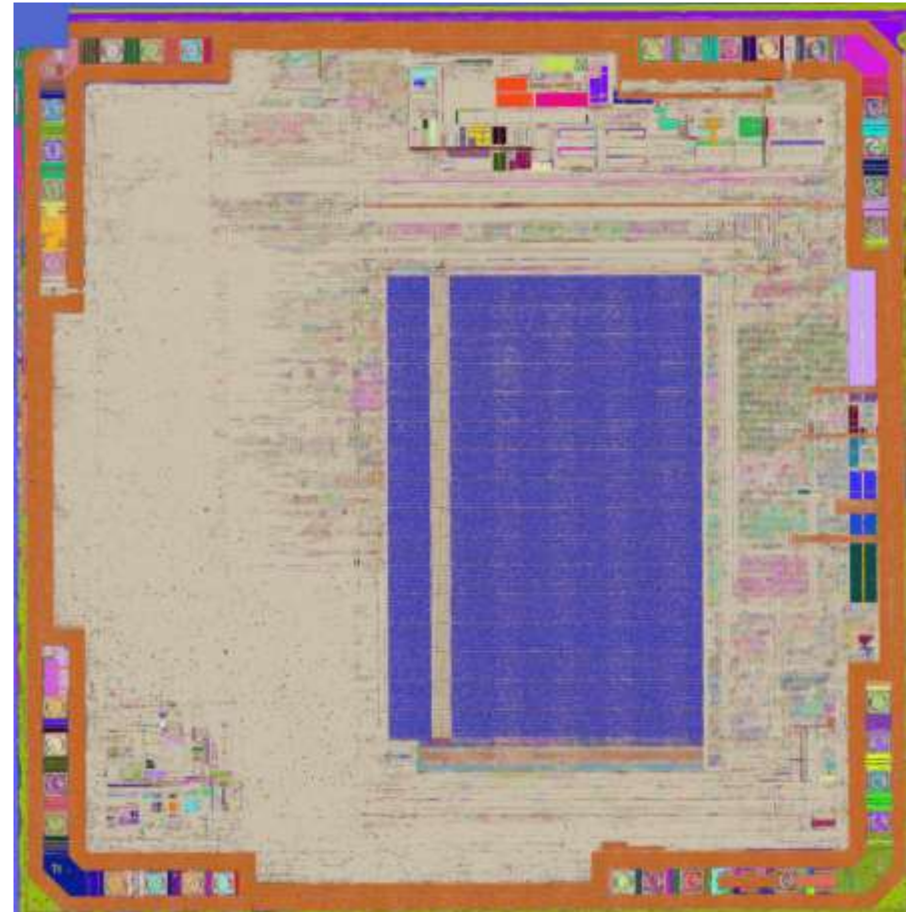


Project Deliverables: Automated Analysis Framework





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Square Area Density Based Spatial Cluster Analysis with Noise (SADBSCAN)

- Method of cluster analysis specifically designed for segmentation and area differentiation in images
- Weights the geographical difference as more important and mark these objects as different clusters
- Queries different regions separately and efficiently
- Calculates simple Euclidian distance of color values
- Combines clusters of pixels based not only on color similarities but also the “geographic” location

Result:

- Accurate feature detection with high speed parallel processing (10-15 minutes on 1GB image)

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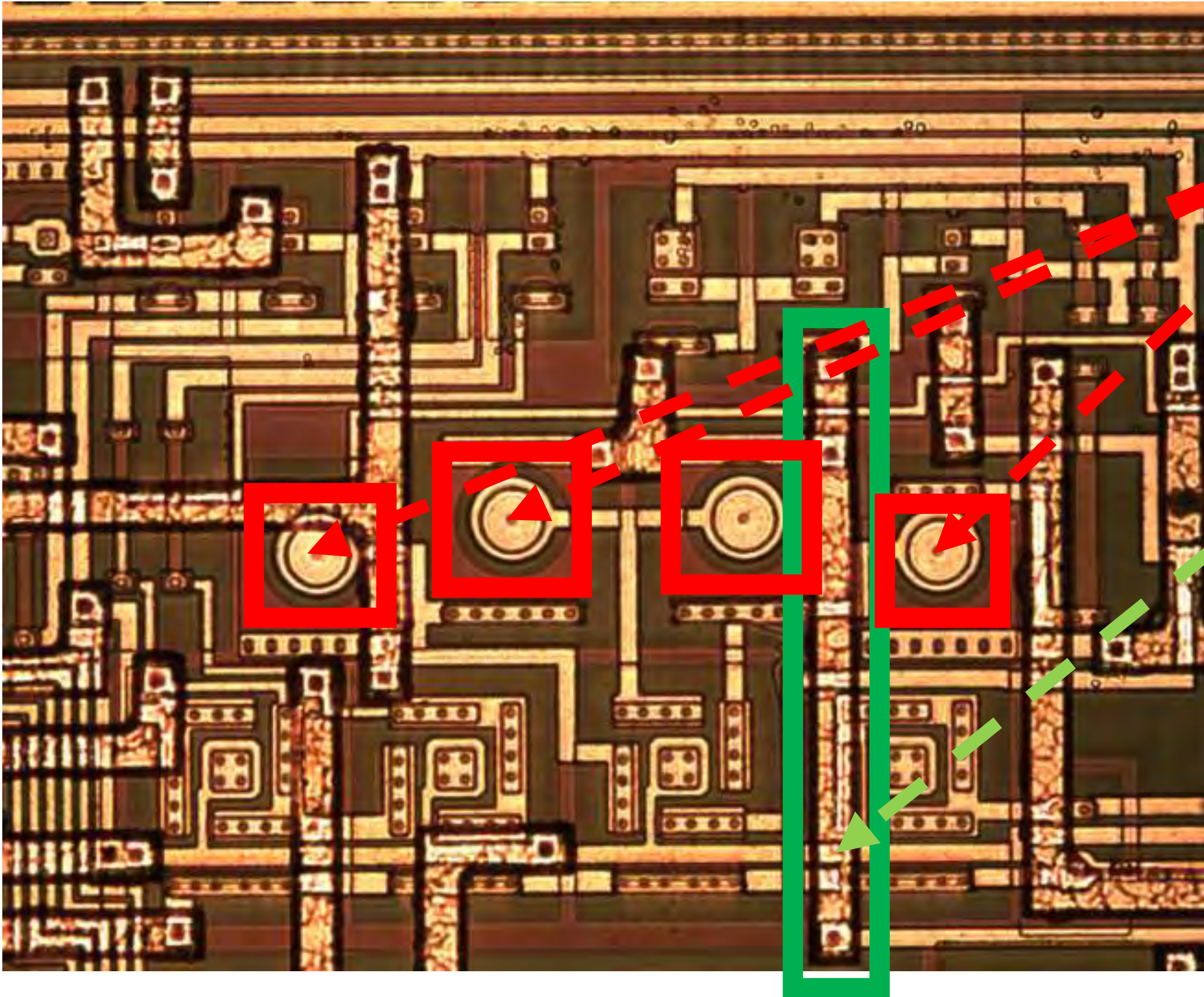
Counterfeit Differences



Circular features, non-45-degree angles

Aluminum, instead of copper

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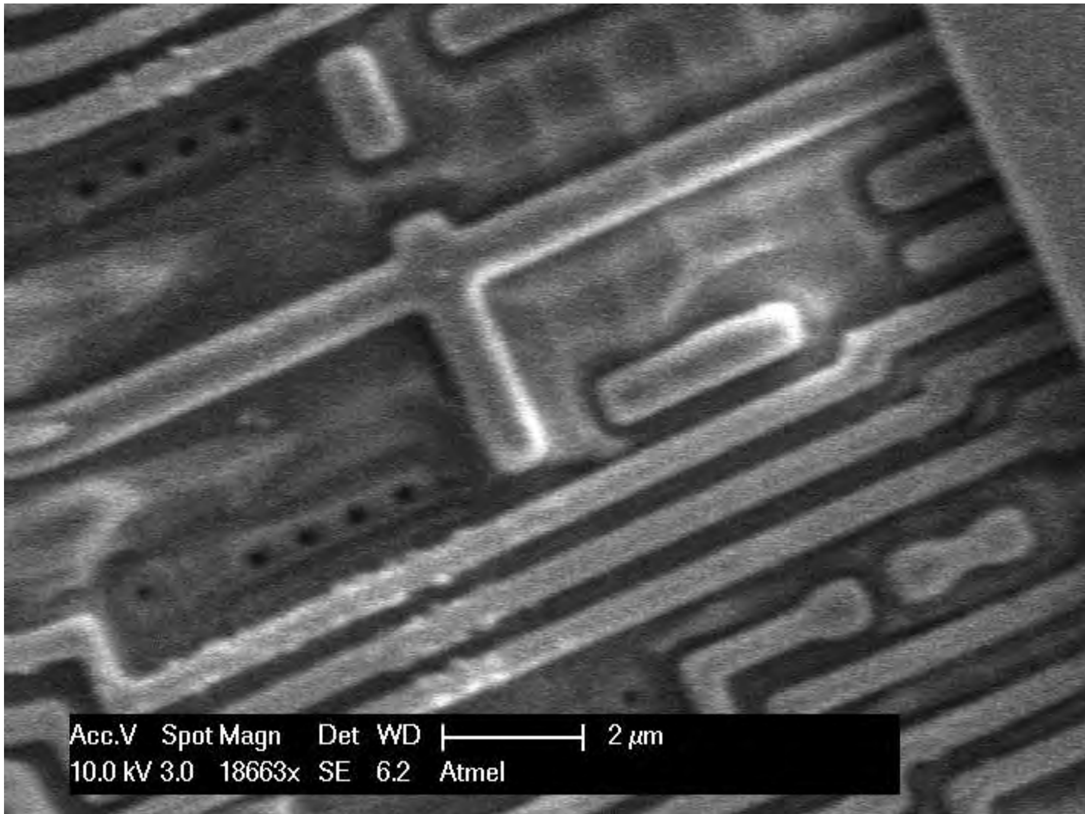
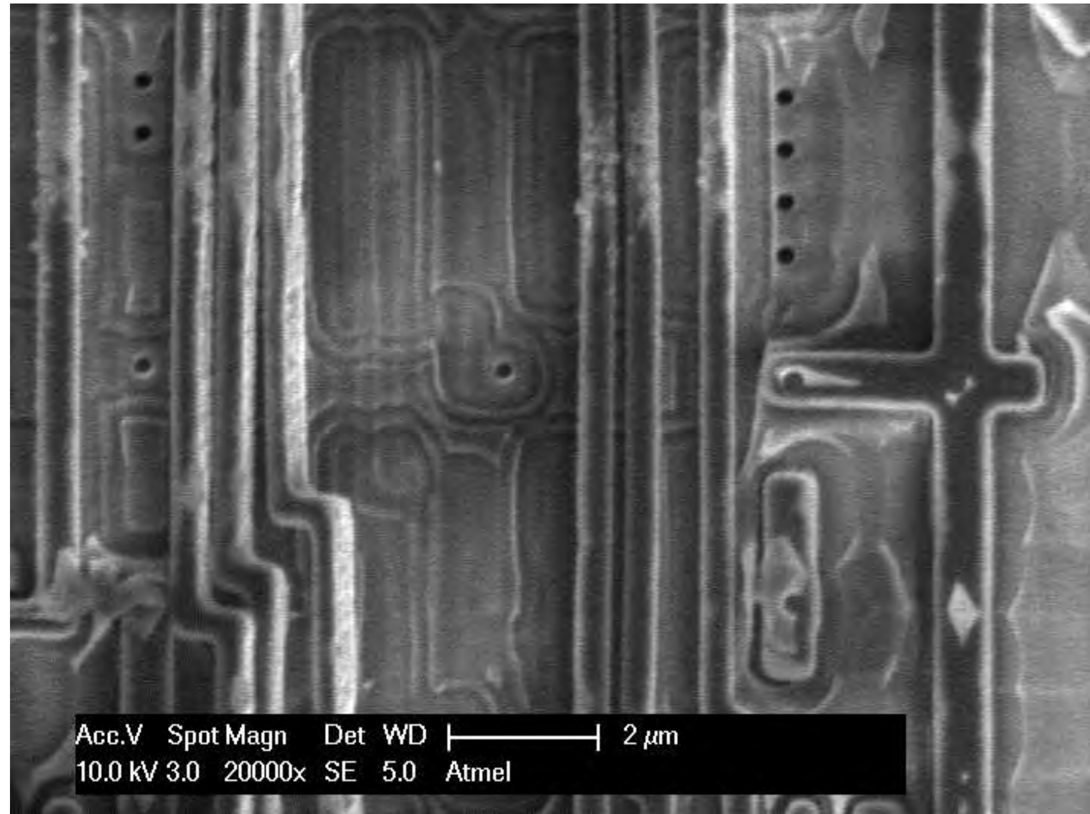
Next Steps





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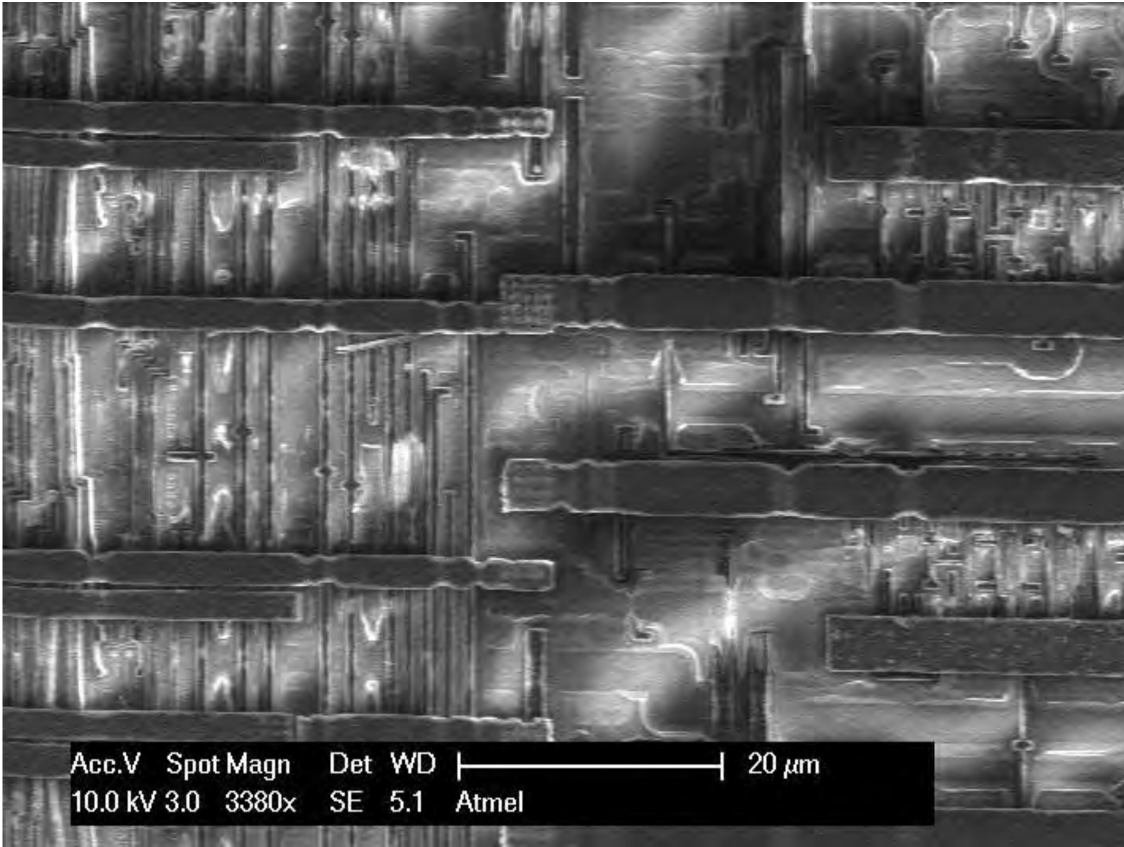

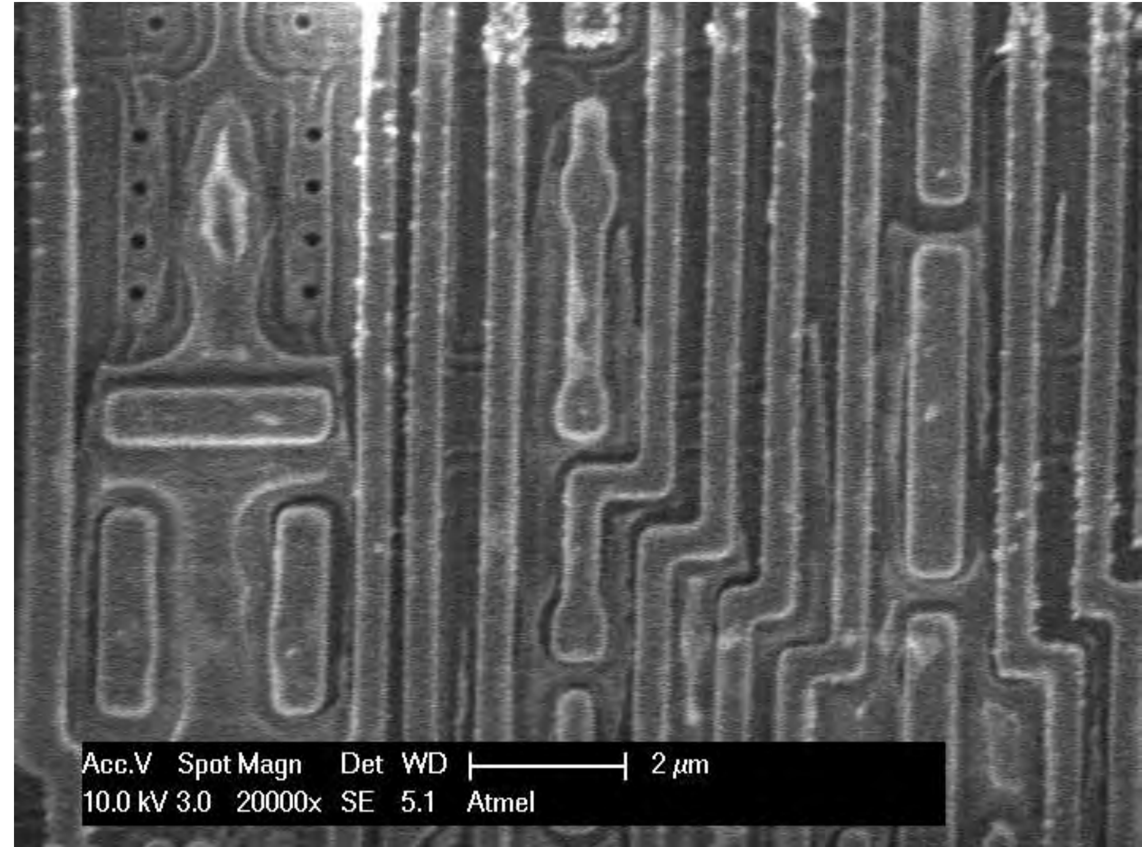

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