SWIR – A Hitchhiker's Guide: Sipping Champagne Riding the Light Waves

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Workshop 2024
ePicture This
An initiative by PENTA/XECS label projects MANTIS, IMAGINATION and ELEVATION supported by AENEAS

Organized by projects: 2020005 Mantis Vision (Penta)
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SWIR Playlist : So-Wrong, It's Right!

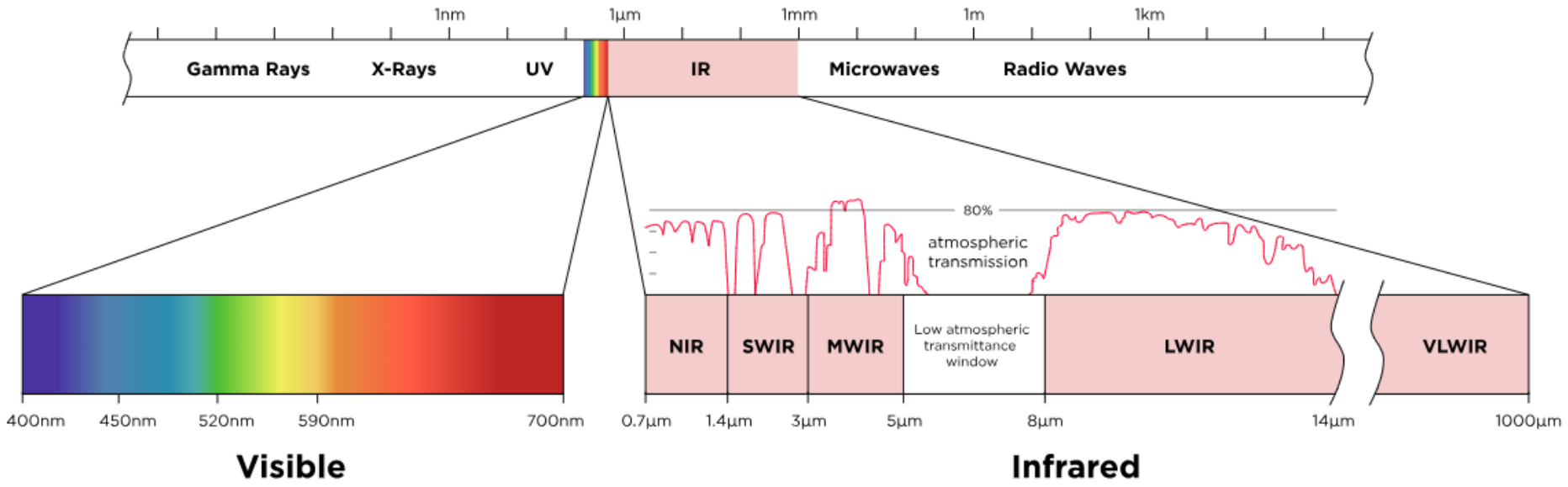
- *Track 1 : Wavelength Wonderland*
  - Discover the mysterious world of SWIR.
- *Track 2 : Let it Roll*
  - SWIR's greatest hits.
- *Track 3 : Timeless Transistors*
  - Travel to an alternate future for a moment.
- *Track 4 : The SWIR Ascension*
  - From the ground to the stars, SWIR is going places.
- *Track 5 : Metrology Melodies*
  - Hit the precise notes of SWIR's role in semiconductor metrology.
- *Track 6 : Front-End to Back-End Beats*
  - SWIR's remix with FEOL to BEOL.
- *Track 7 : Encore - The SWIR Legacy Continues*
  - Pop the bubbly—SWIR's future is bright!

Track 1 : Wavelength Wonderland

Discover the mysterious world of SWIR

What is SWIR ?

- Short-Wave Infra-red (1400 to 3000 nm)
- Extended family (NIR) ~ 700 to 1400 nm .



Source : [INFINITI Optics]

Why SWIR ?

- SWIR experiences less scattering in the atmosphere.
- Effective for imaging through haze, smoke, or fog.

Sony's SWIR Technology

Source : Sony

SWIR Market on the Rise

Net worth

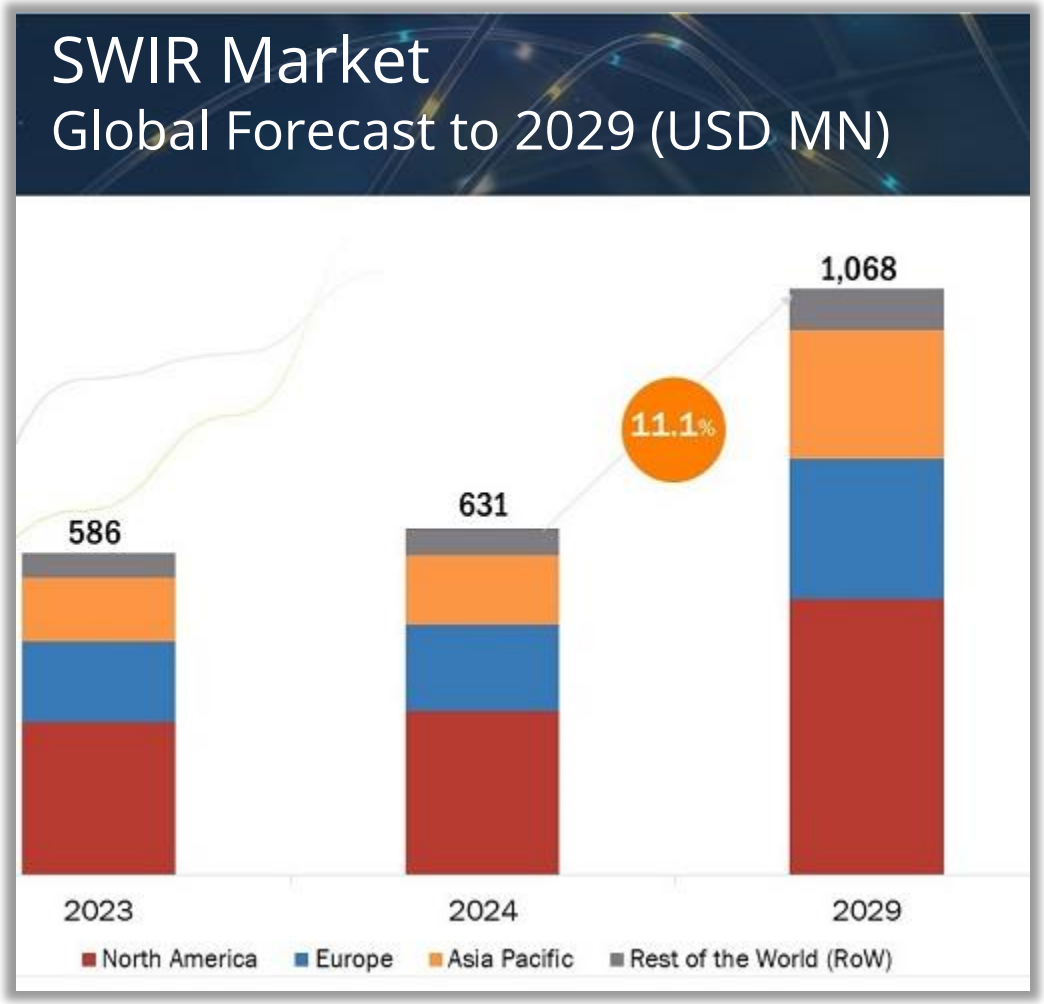
Estimated to be worth USD 1,068 million by 2029.

Growth Rate

Compound annual growth rate (CAGR) ~ 11.1 %

Market Surge

The market's growth can be attributed to the development of more affordable and user-friendly SWIR imagers.

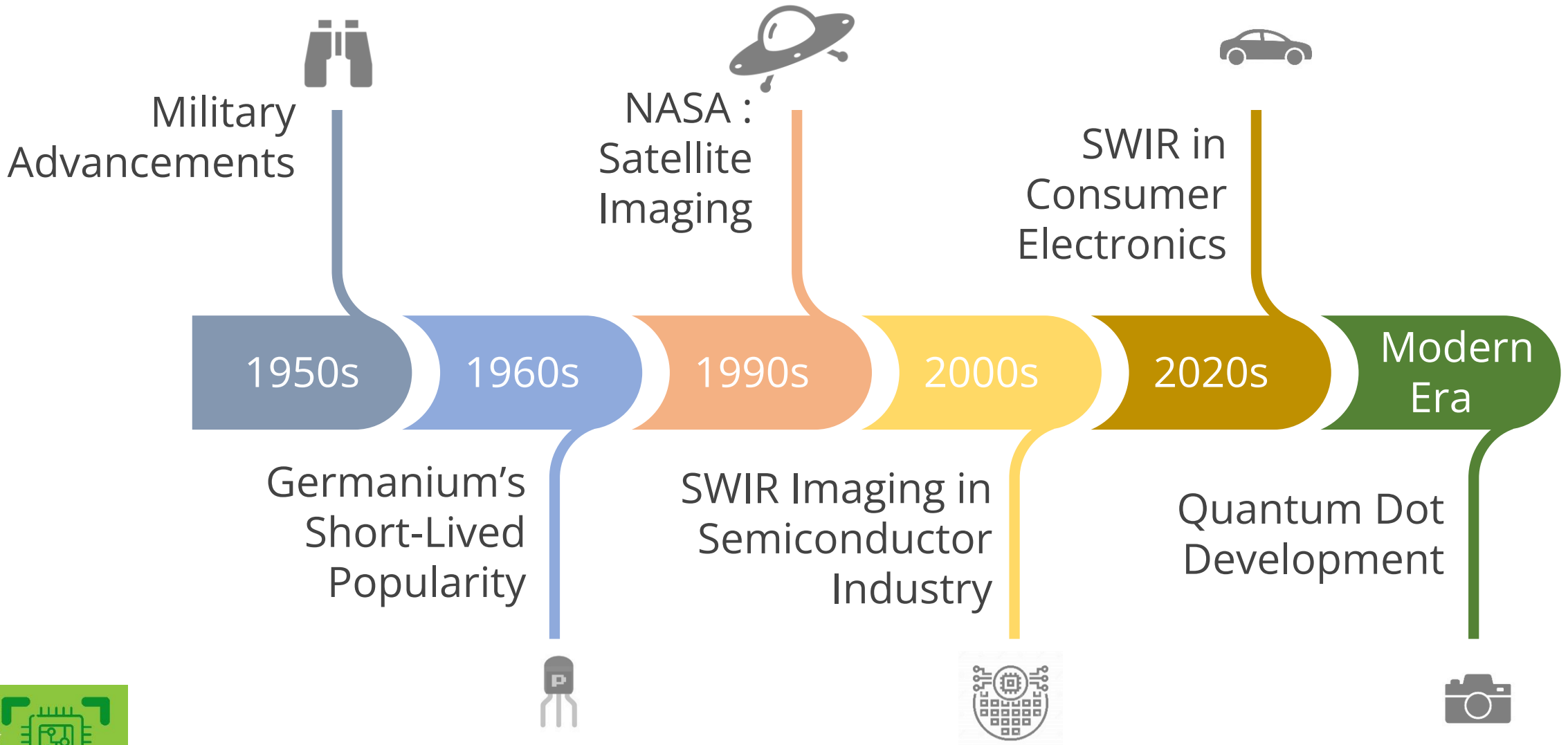


Source : Markets-And-Markets

Track 2 : Let It Roll

SWIR's Greatest Hits

SWIR's Journey



Military Advancements

- Pivotal role in military surveillance and night vision during the Cold War.
- Detectors developed for seeing through fog and smoke.

NASA's Satellite Imaging

- Use of SWIR for environmental monitoring.
- Monitoring of drought conditions and forest fires from space.

1950s

1960s

1990s

Germanium’s Short-Lived Popularity

- Ge plays a critical role in early IR detection.
- Replaced by Si in many electronics due to its abundance and ease of manufacturing.

Source : Vecteezy

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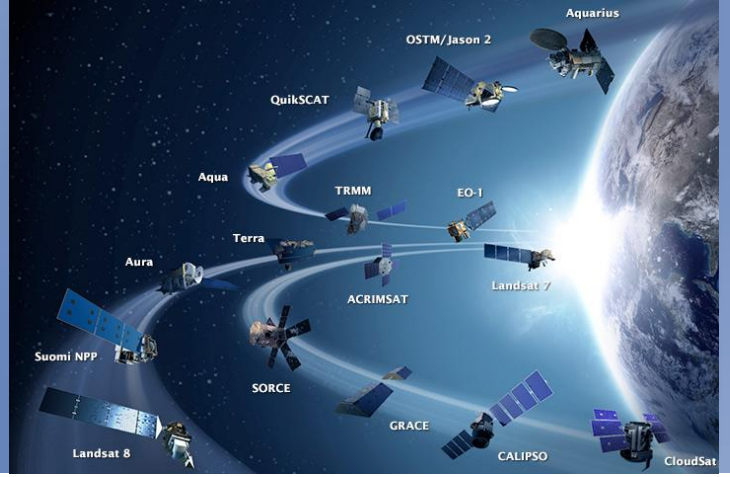

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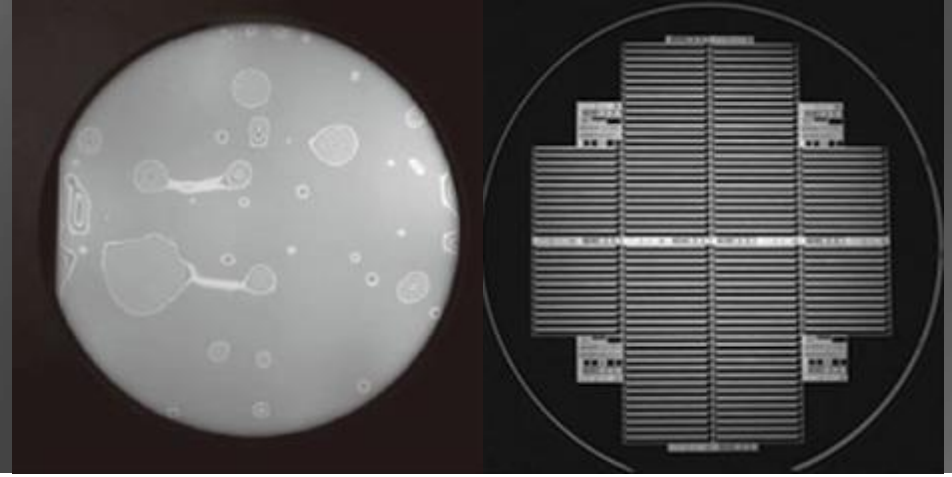
Source : NASA



SWIR Imaging in Semiconductor Industry

- SWIR can penetrate through Si wafers, detecting flaws in integrated circuits.
- Enhances microelectronics quality and refines manufacturing techniques.

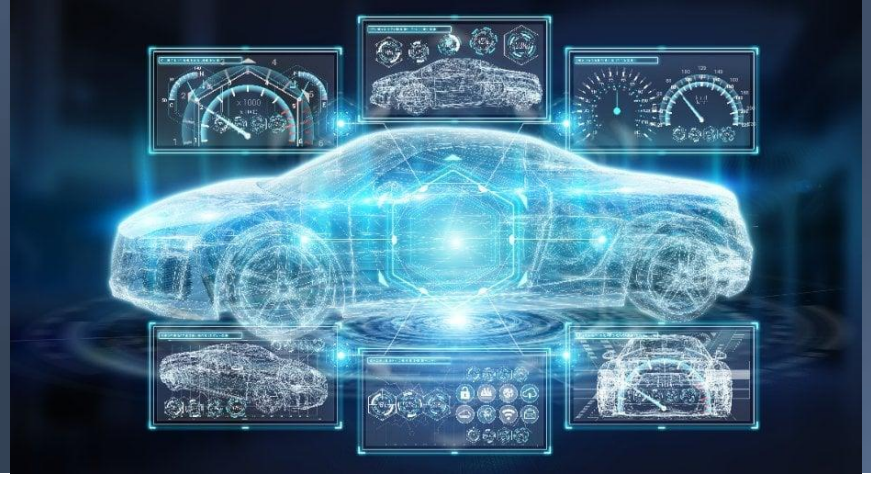
2000s

2020s

SWIR in Consumer Electronics

- SWIR sensors are integrated into smartphones for facial recognition.
- SWIR cameras enhance navigation capabilities in self-driving cars.

Source : R.J. Wilson, Inc.



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Source : Edge Alliance

Track 3 : Timeless Transistors

Alternate Future

The Age of Germanium Transistors

Germanium Era (1947)

Ge was initially the material of choice for transistors, due to excellent electrical properties.

1

Silicon Takeover

Si became dominant due to abundance, lower cost, and better high-temperature performance.

2

Industry Shift

The semiconductor industry transitioned to silicon-based technologies in the mid-20th century.

3

Source : Wikimedia

Alternate Future : Germanium Dominance

1

Continued Ge Development

If Ge had remained the primary material, SWIR technology might have advanced faster.

2

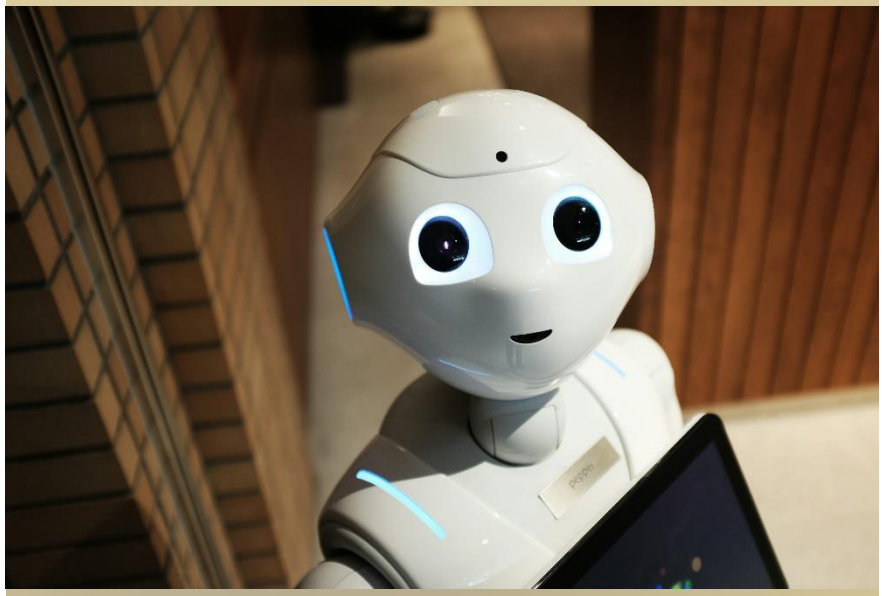
Early SWIR Integration

SWIR-sensitive devices could have been developed much earlier.

3

Widespread Adoption

SWIR technology might have become commonplace in consumer electronics.



Source : Unsplash

Track 4 : The SWIR Ascension

From Ground to Stars

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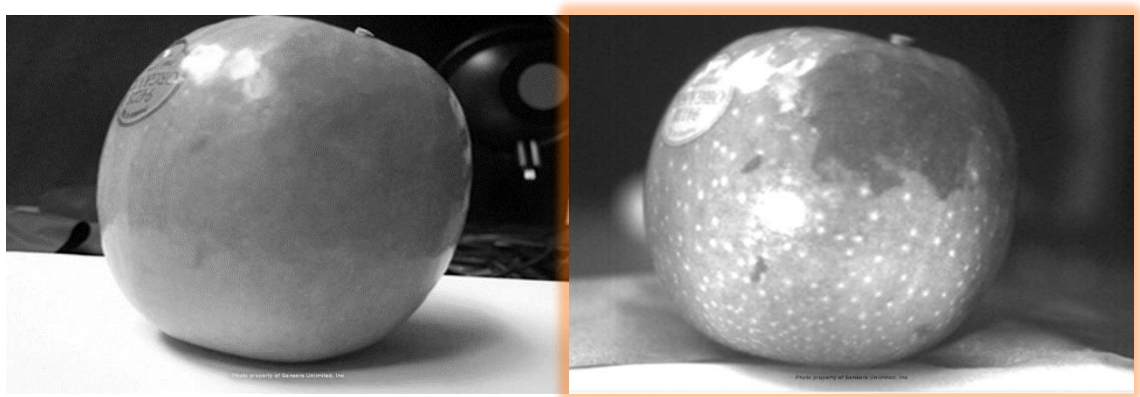
Driver Vision Enhancement

Visible *SWIR*

Advantages :
- Improved low-light performance
- Enhanced contrast and details
- Reduced glare and reflections.

Produce Inspection



Visible *SWIR*

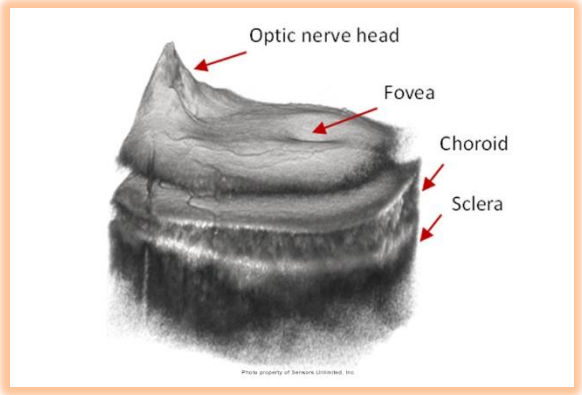
Advantages :
- Moisture Content Detection
- Penetration through Packaging

Maritime Applications

Thermal *SWIR*

Advantages :
- Improved Target Identification
- Greater Spatial Resolution
- Reduced False Alarms.

Medical Imaging



SWIR

Advantages :
- Penetration of Ocular Media
- Non-invasive imaging
- Safe for the human eye.

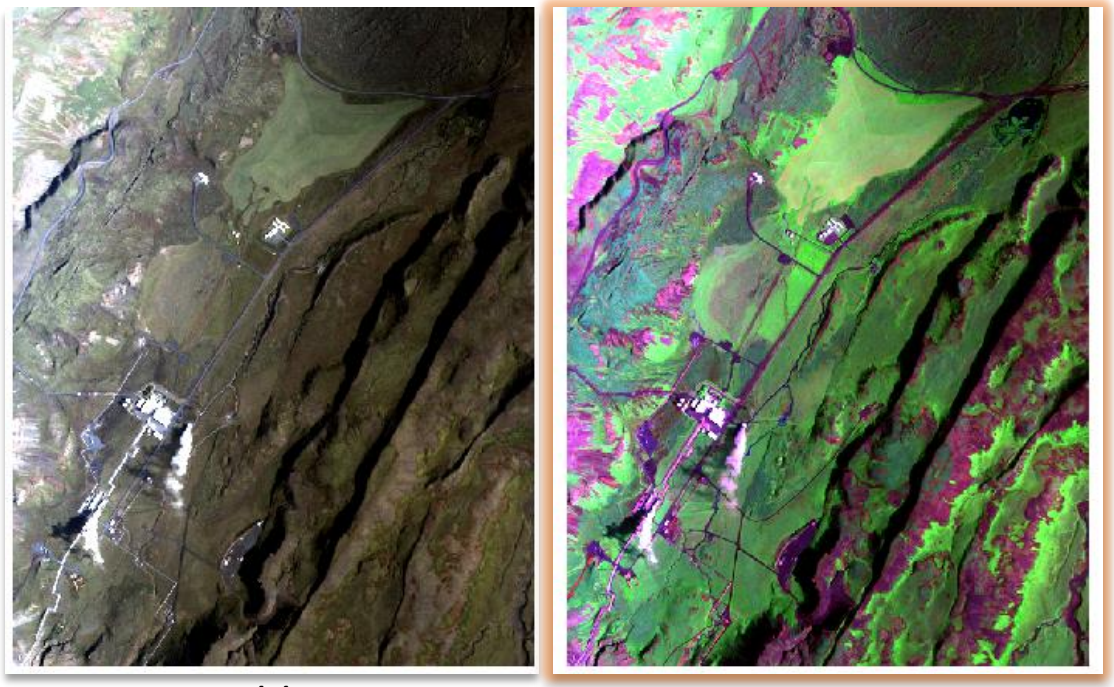
Source : Sensors Unlimited

Satellite Imaging

Visible *SWIR*

Advantages :
- Improved thermal detection
- Reduced atmospheric absorption
- Higher spatial details.

Remote Sensing Applications



Visible *SWIR*

Advantages :
- Highlights different landscape/vegetation features
- Geological and Mineral Mapping.

Track 5 : Metrology Melodies

Hit the precise notes of SWIR's role in semiconductor metrology

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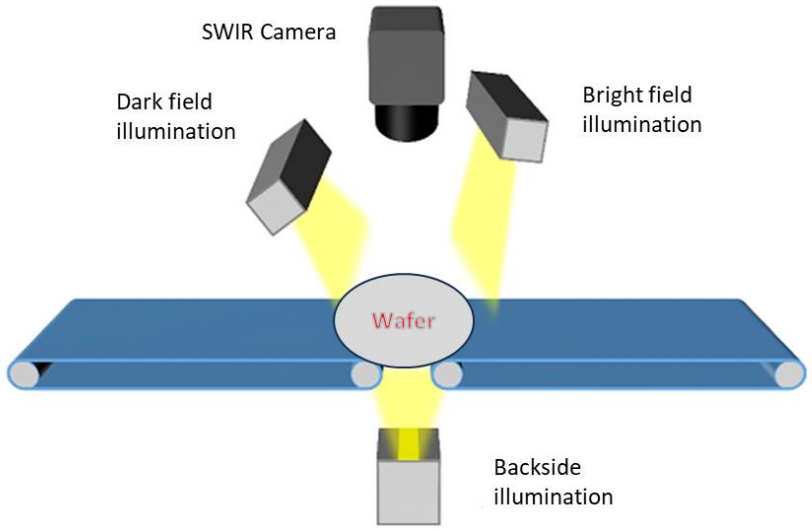


The Role of SWIR in Semiconductor Manufacturing

1 Metrology

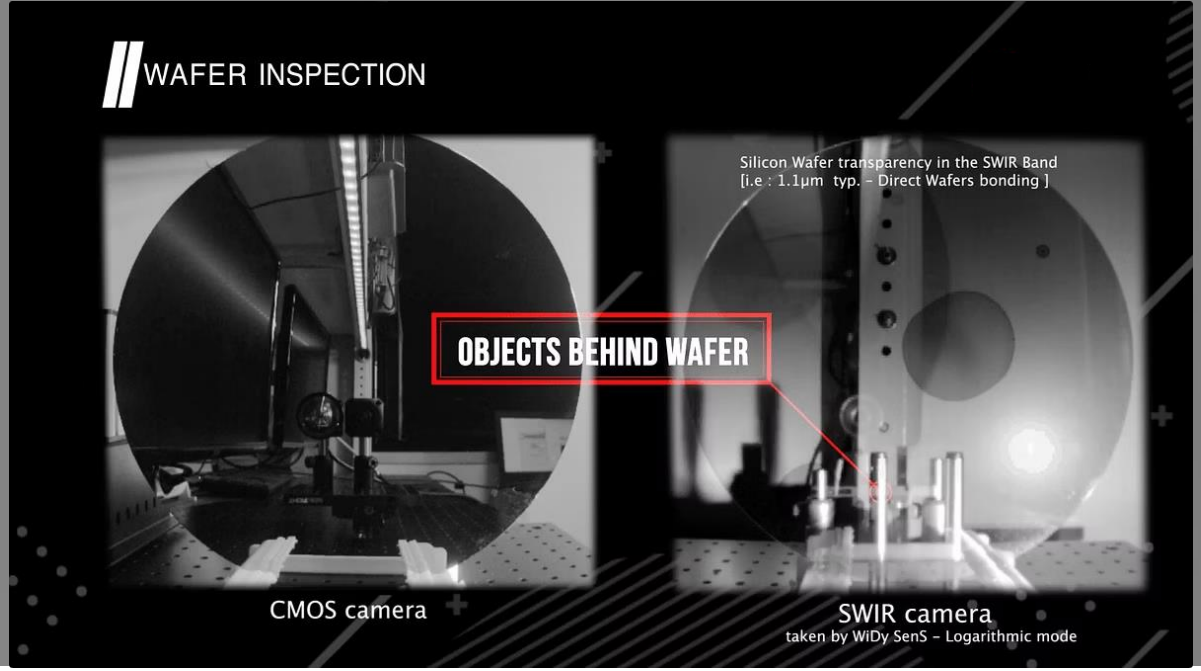
Involves measuring tiny features on silicon wafers, down to the nanometer scale.

2 Non-Destructive Testing

Real-time, in-line inspections to ensure that layers are deposited correctly without compromising the wafer's integrity.

3 Material Analysis

Fourier-Transform Infrared (FTIR) Spectroscopy provides high-resolution spectral data, improving the accuracy of metrology in advanced node manufacturing processes.



Wafer Inspection

1 Quality Improvement

SWIR provides a more transparent image compared to visible light, enhancing inspection quality.

2 Defect Detection

Air trapped between wafers during wafer-to-wafer direct bonding can be detected using SWIR imaging.

3 Component Observation

SWIR can penetrate the silicon layers, making underlying components on a chip more visible.

Source : NIT

Track 6 : Front-End to Back-End Beats

SWIR's remix with FEOL to BEOL

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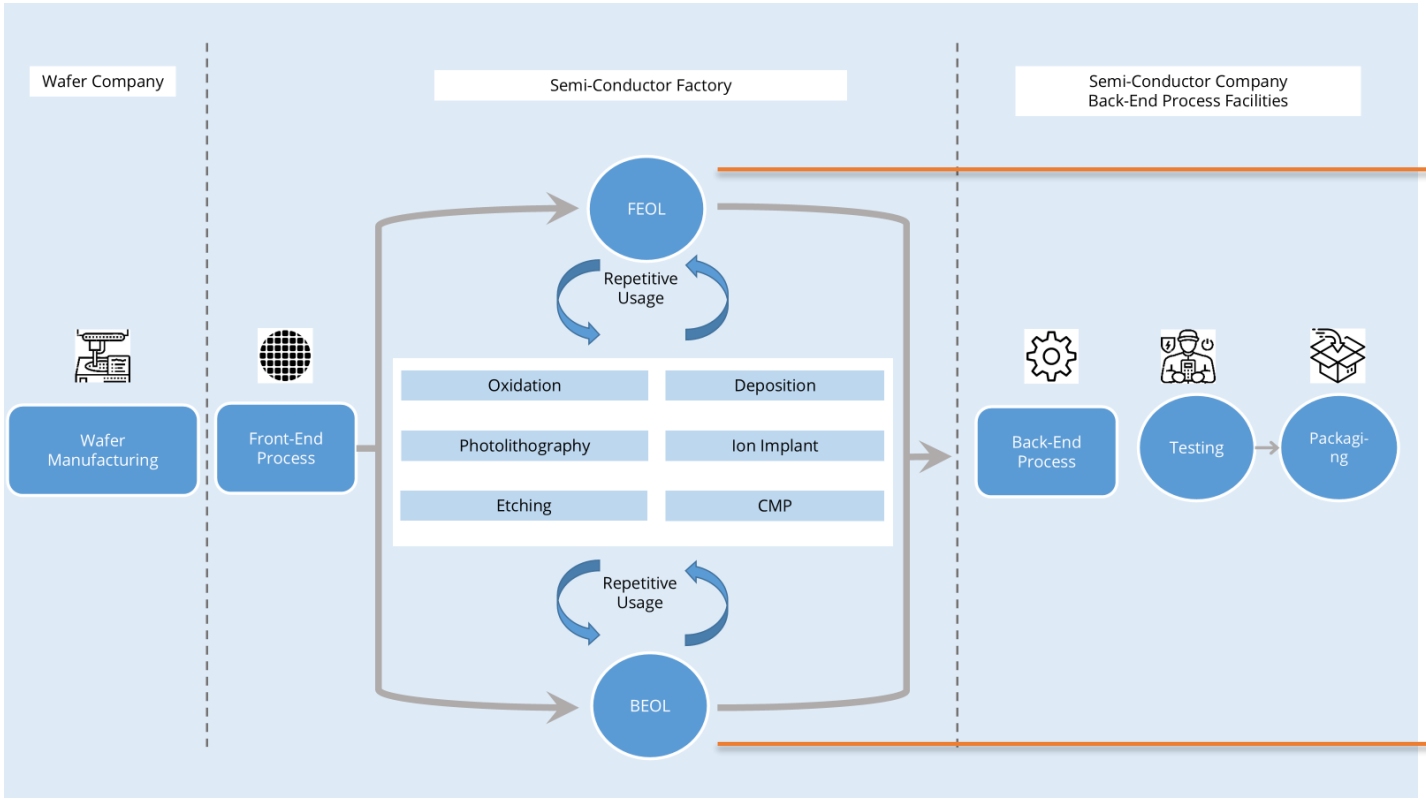
SWIR's Remix with FEOL to BEOL



Integration of SWIR Technology in FEOL :

- Selection of IR sensitive materials like InGaAs.
- Fabrication of multi-layer structures to facilitate efficient light coupling and reduce reflection losses.

Integration of SWIR Technology in BEOL : Hybrid Integration of SWIR sensors with complementary technologies like CMOS

Track 7 : Encore - The SWIR Legacy Continues

A Bright Future Ahead

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Encore - The SWIR Legacy Continues

A New Chapter Begins

- Image Sensor Group at TUD
- The team is making substantial progress in SWIR technology [Supervision by Dr. Padmakumar Rao].

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Mission

To develop post-processable and CMOS-compatible technology for image sensors with a wide spectral bandwidth, covering visible and SWIR ranges.

A Bright Future

Investigation of low-temperature crystalline growth at TUD is a significant leap forward for a bright future in the world of SWIR technology.

Let's Rewind

1

Unique Wavelength Range

- SWIR (+NIR) operates between 700-3000 nm.
- Captures details invisible to the naked eye.

2

Market Growth Potential

- Projected to exceed $1 billion by 2029.
- The growth is fueled by the demand for improved imaging solutions in challenging conditions.

3

Historical Significance

- From military applications to modern uses in NASA satellite imaging, smartphones, and self-driving cars.

4

Precision in Manufacturing

- Essential for non-destructive inspection in semiconductor manufacturing, ensuring high-quality devices.

5

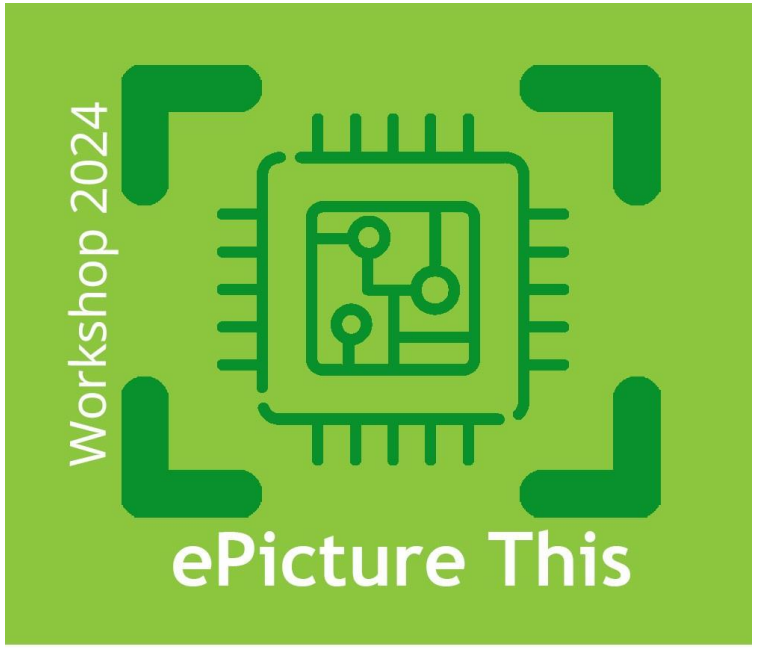
Diverse Applications

- Expanding into sectors such as healthcare, remote sensing, environmental monitoring, and space exploration, opening new frontiers for innovation.

6

TUD's Progress :

- A low-temperature, CMOS-compatible, process is proposed.



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