Challenge 1 – IEEE IRDS 2023: Beyond CMOS

Overview

The 2023 IEEE IRDS "Beyond CMOS" chapter explores emerging technologies poised to succeed traditional CMOS as it approaches its physical and performance limits. This roadmap categorizes and evaluates novel devices and architectures based on their operational principles and potential applications.

Scope and Objectives

The "Beyond CMOS" focus team aims to:

> Survey and assess viable emerging devices and novel architectures for their long-range potential and technological maturity.
>
> Identify scientific and technological challenges impeding their acceptance by the semiconductor industry.
>
> Provide an objective resource for nanoelectronics communities involved in research, tool development, funding, and investment.

Device Categories

The IRDS classifies Beyond CMOS devices into three primary categories:

1. CMOS Extension Devices

These aim to enhance current CMOS technology through innovations like:

> Gate-All-Around FETs (GAAFETs)
>
> Nanosheet transistors

2. Charge-Based Beyond CMOS Devices

Devices that utilize charge manipulation in novel ways, including:

Negative Capacitance FETs (NC-FETs)

Tunneling FETs (TFETs)

Ferroelectric FETs (FeFETs)

3. Non-Charge-Based Beyond CMOS Devices

These rely on alternative state variables, such as:

Spintronics

Magnetoelectric Devices

Emerging Computing Paradigms

Beyond CMOS technologies enable new computing architectures, including:

In-Memory Computing: Integrates memory and processing units to reduce data movement, enhancing speed and energy efficiency.

Neuromorphic Computing: Mimics neural networks using devices like memristors to achieve brain-like processing capabilities.

Quantum Computing: Utilizes quantum bits (qubits) for complex computations, potentially solving problems intractable for classical computers.

Challenges and Considerations

The transition to Beyond CMOS technologies faces several hurdles:

Material Integration: Developing and integrating new materials compatible with existing fabrication processes.

Manufacturing Scalability: Ensuring that novel devices can be produced at scale with high yield and reliability.

Design and Simulation Tools: Creating accurate models and tools to design and predict the behavior of emerging devices.

Standardization: Establishing industry-wide standards for new device architectures and interfaces.

Benchmarking and Evaluation

The IRDS emphasizes the importance of benchmarking emerging devices against CMOS standards to evaluate their potential. Key performance metrics include:

Energy-Delay Product: Assessing the trade-off between energy consumption and operational speed.

Scalability: Evaluating the feasibility of device miniaturization.

Integration Compatibility: Determining the ease of integrating new devices with existing systems.