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SEMICONDUCTOR MANUFACTURING IN INDIA

SYLLABUS:

GS 3> Industry and infrastructure

REFERENCE NEWS:

- India's semiconductor sector is projected to expand very rapidly over the next decade. According to a recent Deloitte report, the market, currently estimated at about **$45–50 billion in FY 2024–25**, is expected to grow to **$120 billion by 2030 and further to $300 billion by 2035.**
- This growth is being driven mainly by rising **demand from AI, automobiles, data centres, and electronics manufacturing.**
- By 2035, mobile phones, automotive, computing, and data centres alone are expected to account for over 70% of total semiconductor demand in India.

HIGHLIGHTS OF REPORT:

- India **currently imports over 90% of its semiconductor needs**, but according to the Deloitte report, a major **shift is expected by 2035**, when local production could **meet more than 60% of domestic demand**, reducing import dependence and enhancing self-reliance.
- The report projects that India could **build a full semiconductor ecosystem by 2035**, including 4–5 silicon fabs, 8–10 compound fabs, 1–2 display fabs, and 20–25 OSAT (Outsourced Semiconductor Assembly and Test) facilities, driven by the India Semiconductor Mission and state incentives.
- It notes that over $19 billion has already been invested across 10 approved projects, with another $20–25 billion in proposals in the pipeline. Further investments of $50 billion in the next five years and $75–80 billion between 2030–2035 are expected.
- The Deloitte report also estimates **around 2 million jobs by 2035**, but stresses that success will depend on execution, long-term policy support, Centre–State coordination, and streamlined clearances.

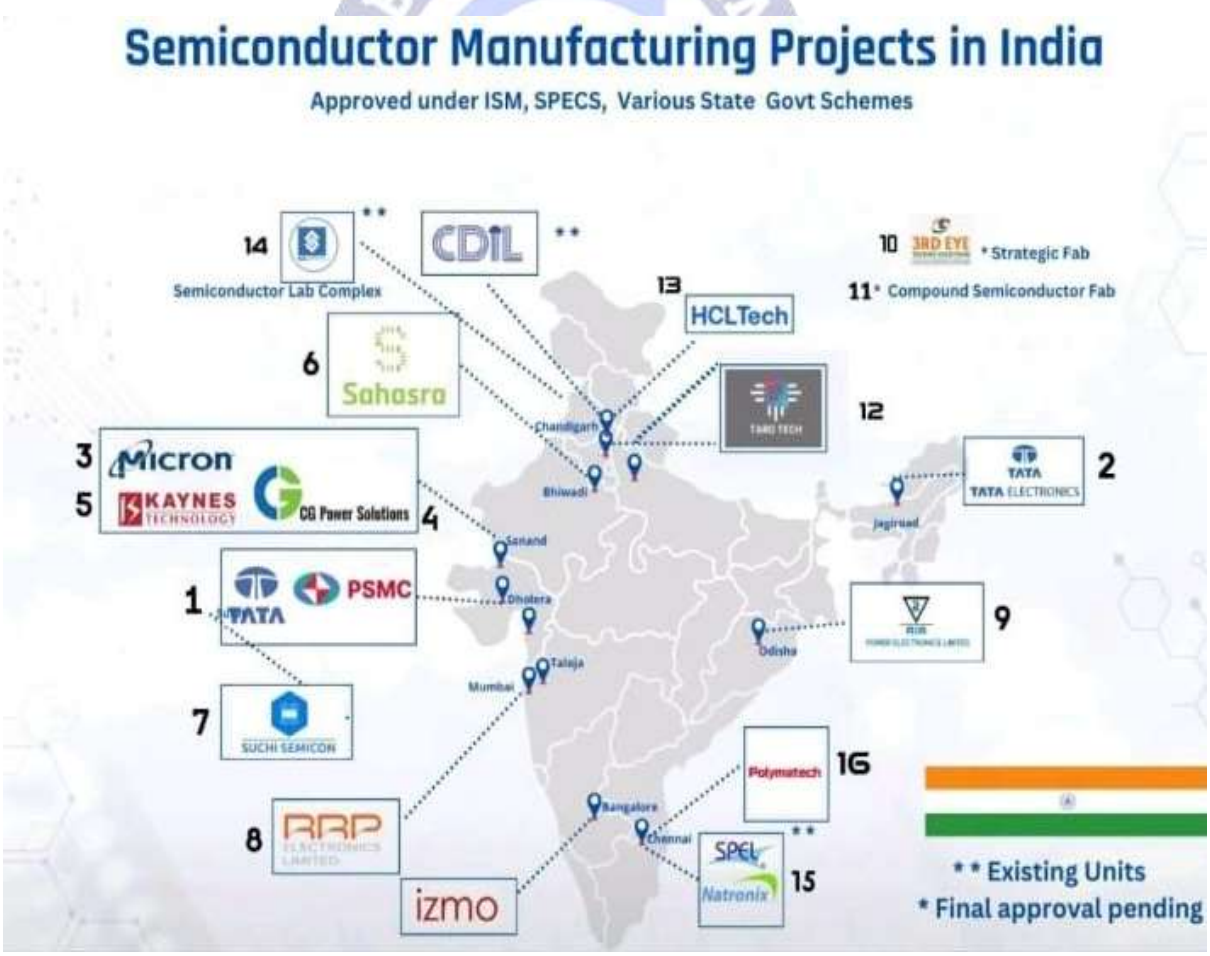
SEMICONDUCTORS:

- A semiconductor material has an electrical conductivity value falling between that of a conductor, such as metallic copper, and an insulator, such as glass. Common elemental semiconductors are **silicon and germanium**.
- Chipsets are the most commonly used semiconductor component. A chipset is a **group of integrated circuits that control the flow of data** and instructions between the central processing unit (CPU) and external devices.

- Their design and development occur in various stages:
  - A **wafer** is designed and manufactured in **wafer fabrication (FAB) units, also called foundries**, by companies as per the requirements of chip manufacturers like Samsung and Qualcomm.
  - The chipmakers then package, test and sell the chips to equipment manufacturers such as Xiaomi and Cisco.
- End-use industries that depend on semiconductors include mobile and telecommunication devices, industrial machinery, automobiles, automation (workplace, healthcare, manufacturing etc.), the Internet of Things (IoT) and other industries that have applications for computing in some form or other.

STATS:

- The current production of electronic components in India is valued at **USD 11 billion** and is expected to reach **USD 18 billion by FY 26.**(Source: Invest India)
- The **Indian semiconductor market**, which is valued at approximately **USD 23.2 billion** and is projected to reach **USD 80.3 billion by 2028**, is growing at a compound annual growth rate (CAGR) of 17.10%.(Source: Invest India)
- India has the requisite expertise in software and chip design. Yet**, India lags in the establishment of semiconductor wafer fabrication (FAB) units**.



SIGNIFICANCE OF SEMICONDUCTOR MANUFACTURING

- **Boost Domestic Manufacturing and Supply Chain Resilience:**
  - India aims to become **self-reliant** in semiconductor manufacturing under the **Atmanirbhar Bharat initiative**, with the vision to emerge as a global hub for electronic system design and semiconductor manufacturing.

- For instance, the **COVID-19 pandemic** highlighted vulnerabilities in global supply chains, especially in the semiconductor industry. By bolstering domestic manufacturing, India can reduce its dependency on international suppliers and enhance **supply chain resilience** against global disruptions.

- **Attract Investment:**
  - India has introduced a **USD10 billion incentive package** under the **Production Linked Incentive (PLI) Scheme for Semiconductors** as part of its broader strategy to establish a robust domestic semiconductor ecosystem. This package, managed by the **India Semiconductor Mission (ISM),** offers up to 50% fiscal support for semiconductor and display manufacturers.
  - The goal is to **attract global chip makers** to set up production bases in India, positioning the country as a key player in the global semiconductor market. Major companies such as **Tower Semiconductor, Foxconn, and Vedanta** have already expressed interest.
- **Employment Generation:**
  - With the advent of **Industry 4.0**, the semiconductor industry will create **highly skilled employment opportunities**. For instance, by developing a strong domestic electronics industry, India can harness its **demographic dividend**, generating jobs in advanced technological sectors.
- **Reap Benefits of the Global Chip Shortage:**
  - The global semiconductor shortage has disrupted industries worldwide, presenting India with an opportunity. By attracting fabrication units through favorable policies, India could enhance its self-reliance in semiconductor production, **meeting domestic and global demands**.
- **Strategic Significance:**
  - Manufacturing and supply of semiconductors are concentrated in countries like **Taiwan, South Korea, Japan, the U.S., and China**. Geopolitical tensions in these regions could disrupt supply chains.
  - For instance, **Taiwan, the world's leading chip producer**, faces tensions with mainland China, posing risks to India's imports. Attaining **self-sufficiency** in semiconductor production can protect India from such geopolitical risks.
- **National Security:**
  - Semiconductors are critical components in **defense technologies**. Ensuring a **domestic supply** of these components protects a nation's security apparatus from unreliable foreign sources, thereby enhancing **national security**.
- **R&D Ecosystem Development:**
  - A robust semiconductor manufacturing sector fosters a vibrant **research and development ecosystem**. For instance, **Silicon Valley** demonstrates how a strong semiconductor industry can attract talent and investments in **cutting-edge technologies**.
- **Technological Sovereignty:**
  - Control over **semiconductor technology** is crucial for **technological sovereignty**. For example, it allows countries to set their own standards and regulations, ensuring independence from foreign entities for critical technologies.
- **Economic Diversification:**
  - Investing in **electronics and semiconductor manufacturing** helps diversify a country's economy, **reducing reliance on traditional industries**.

- For example, **Taiwan's economy** shows how its thriving semiconductor industry has contributed to **economic growth** and diversification.

- **Promote Circular Economy:**
  - A **circular electronics system**, where resources are reused in multiple ways, fosters **sustainability** and enhances **cost-effectiveness**. For instance, building a reliable domestic semiconductor manufacturing base is essential to develop such sustainable systems.
- **Boost to Startups and SMEs:**
  - Readily available, affordable domestically made chips support local hardware start-ups and SMEs, fostering indigenous innovation and reducing barriers to entry in electronics manufacturing.
- **Regional Development and Infrastructure Growth:**
  - Semiconductor fabs drive the development of essential infrastructure (clean power, water, logistics), leading to regional economic upliftment, especially in emerging industrial zones.

CHALLENGES:

- **Capital intensive industry:**
  - A semiconductor fabrication facility can cost multiples of a billion dollars to set up even on a relatively small scale. They also have high operating costs and need frequent technology replacement. This makes it a **viable industry for only a few corporate giants**.
- **Power demand:**
  - Chip fabs require extremely stable power supply. But this is a challenge in India.
  - For instance, India recorded a power supply **shortage of 1,201 million units in October 2021** — the highest in 5.5 years — due to coal shortage in thermal plants. This example highlights **the ongoing challenges in ensuring consistent power supply,** an issue that persists even in 2024, as India continues to face coal-related shortages impacting power generation in several states.
- **Concerns over water use:**
  - Semiconductor manufacturing requires large volumes of **ultra-pure water** to avoid the contamination of electronic devices. For a **water stressed country** like India, such levels of water usage are unsustainable.
  - For instance, Taiwan Semiconductor Manufacturing Company uses around **60 liters of water per layer of chip** and the recent severe drought in Taiwan has affected production.
- **Stiff competition:**
  - India has a weak ecosystem and shortage of resources as compared to more competitive bases **like China and Vietnam**. Hence, it would require immense government support to attract the industries to the country.
- **Challenges and Previous Attempts:**
  - Previous attempts to establish semiconductor fabrication facilities in India faced challenges. Notably, a **joint venture between Foxconn and Vedanta**, aimed at setting up a **USD 19.5 billion chip plant, was dissolved**.
  - Additionally, Tower Semiconductor's initial **proposal for a USD 3 billion plant in Karnataka was stalled** due to its then impending merger with Intel, which was **eventually cancelled due to regulatory hurdles.**
- **Environmental concerns:**

- India is the **third largest producer of e-waste,** generating about 2.4 kg of e-waste per capita. The arrival of new industries would increase the amount of e waste generated in the country.

- **Supply Chain Dependence on Imports:**
  - India heavily relies on imports for critical semiconductor manufacturing materials and high-end equipment (e.g., photolithography machines, specialty gases). This creates a **strategic vulnerability**.
- **Limited Domestic R&D in Core Manufacturing Technologies**
  - While India excels in chip design, it lags in **advanced research** for fabrication processes, materials science, and chip-making equipment—hindering innovation and self-reliance in manufacturing.
- **Long Gestation Period and High Risk for Investors**
  - Semiconductor fabs take **5–10 years to become profitable**, and rapidly evolving technology makes such investments risky. This deters private sector participation without long-term state support.
- **Talent Gap in Niche Roles**
  - There's a shortage of professionals skilled in **process engineering, photonics, wafer inspection, and ATMP operations**, despite a large engineering workforce. India also faces **brain drain** in these niche areas.

- **Inadequate ATMP Ecosystem**
  - The Assembly, Testing, Marking, and Packaging segment is **underdeveloped**, leading to continued reliance on countries like Malaysia, Vietnam, and Taiwan for back-end processes.
- **Policy and Regulatory Uncertainty**
  - **Delays in approvals, land acquisition bottlenecks**, and lack of **clarity in fiscal incentives** across states lead to investor hesitation and stalled projects.

GOVERNMENT EFFORTS:

- **India Semiconductor Mission(ISM)**
  - India Semiconductor Mission (ISM) has been setup as an **Independent Business Division within Digital India Corporation.**

    Digital India Corporation has been set up by **the Ministry of Electronics & Information Technology**, Government of India, to innovate, develop and deploy ICT and other emerging technologies for the benefit of the common man. It is **a 'not for profit' Company** under Section 8 of the Companies Act 2013. The Company has been **spearheading the Digital India programme** of the Government of India, and is involved in promoting use of technology for eGovernance/ e-Health / Telemedicine, e-agriculture, e-Payments etc
  - ISM has all the **administrative and financial powers** and is tasked with the responsibility of catalysing the India Semiconductor ecosystem in manufacturing, packaging and design.
  - ISM has been working as **nodal agency** for the Schemes approved under **Semicon India Programme.** The **applications were received by ISM and are being appraised by ISM.** ISM has also been engaging with various stakeholders of Semiconductors and Display ecosystem to attract the investments in India.
- **Semicon India Programme:**

- The government has approved the Semicon India programme with a total outlay of INR 76,000 crore for the development of semiconductor and display manufacturing ecosystems in the country.
- The following four schemes have been introduced under the programme:
  1. **Modified Scheme for setting up of Semiconductor Fabs in India**.
  2. **Modified Scheme for setting up of Display Fabs in India**.
  3. **Modified Scheme for setting up of Compound Semiconductors / Silicon Photonics / Sensors Fab / Discrete Semiconductors Fab and Semiconductor Assembly, Testing, Marking and Packaging (ATMP) / OSAT facilities in India**.
  4. **Semicon India Future Design: Design Linked Incentive (DLI) Scheme.**

- **National Policy on Electronics 2019 (NPE 2019):**
  - The National Policy on Electronics 2019 (NPE 2019) aims to establish **India as a global hub for Electronics System Design and Manufacturing (ESDM).**
- **PLI Scheme for Large Scale Electronics Manufacturing:**
  - Under the scheme, electronic manufacturing companies will get an **incentive of 4 to 6% on incremental sales** (over base year) of goods manufactured in India and covered under target segments, to eligible companies over a period of next 5 years.
- **Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS):**
  - Under the scheme, a financial incentive of 25% of capital expenditure has been approved by the Union Cabinet for the manufacturing of goods that constitute the supply chain of an electronic product.
- **Modified Electronics Manufacturing Clusters (EMC 2.0) Scheme:**
  - The scheme will provide financial assistance up to 50% of the project cost subject to a ceiling of Rs 70 crore per 100 acres of land for setting up of Electronics Manufacturing Cluster projects.
- **Indigenous GPU Development:**
  - India plans to roll out a prototype of its indigenous Graphics Processing Unit (GPU) by the end of 2025. This initiative is part of the country's efforts to reduce dependence on imported semiconductor components and enhance self-reliance in critical technologies.
- **SHAKTI-Based Aerospace Chip Development**
  - IIT Madras and ISRO have jointly developed a 64-bit IRIS (Indigenous RISC-V Controller for Space Applications) chip based on the SHAKTI processor.
  - This chip is tailored for space applications and represents a significant step in **indigenous aerospace semiconductor development.**

WAY FORWARD:

- **Fast-track Regulatory Clearances**
  - Establish a **single-window clearance system** for semiconductor projects to streamline land acquisition, environmental approvals, and fiscal incentives.
- **Strengthen Infrastructure Backbone**
  - Prioritize development of **reliable power and water supply**, high-speed connectivity, and plug-and-play industrial clusters near semiconductor hubs.
- **Develop a Skilled Talent Pipeline**
  - Expand semiconductor-focused curricula through partnerships with **academic institutions**, ISM, and industry leaders.

- Deploy initiatives like **Semiconductor Learning Kits** and internships to create an **industry-ready workforce**.

- **Enhance Research & Innovation Ecosystem**
  - Support public-private R&D collaboration through grants, centers of excellence (like BSRC), and **indigenous IP creation** in chip design and fabrication.
- **Encourage Global-Local Collaborations**
  - Promote **joint ventures, technology transfers**, and strategic tie-ups with leading global semiconductor firms to integrate India into **global value chains**.

- **Ensure Environmental Sustainability**
  - Adopt **green manufacturing practices**, water recycling technologies, and enforce stringent **e-waste management protocols** to make the industry future-ready.
- **Facilitate Access to Capital**
  - Provide **viability gap funding**, promote **venture capital access**, and extend **sovereign backing** to startups and MSMEs in semiconductor design, ATMP, and innovation.
- **Geopolitical and Trade Integration**
  - Align with strategic multilateral groupings like the **Quad, IPEF**, and engage in **bilateral technology agreements** to enhance semiconductor trade and security cooperation.
- **Build Domestic Semiconductor Tooling and Materials Capacity**
  - Invest in the development of **indigenous equipment, chemicals, and ultra-pure materials**, reducing import dependence and increasing supply chain security.
- **Promote India as a Trusted Manufacturing Destination:**
  - Position India as a geopolitically stable, rule-of-law-based alternative to high-risk regions for global chipmakers seeking diversification **(China+1 strategy).**

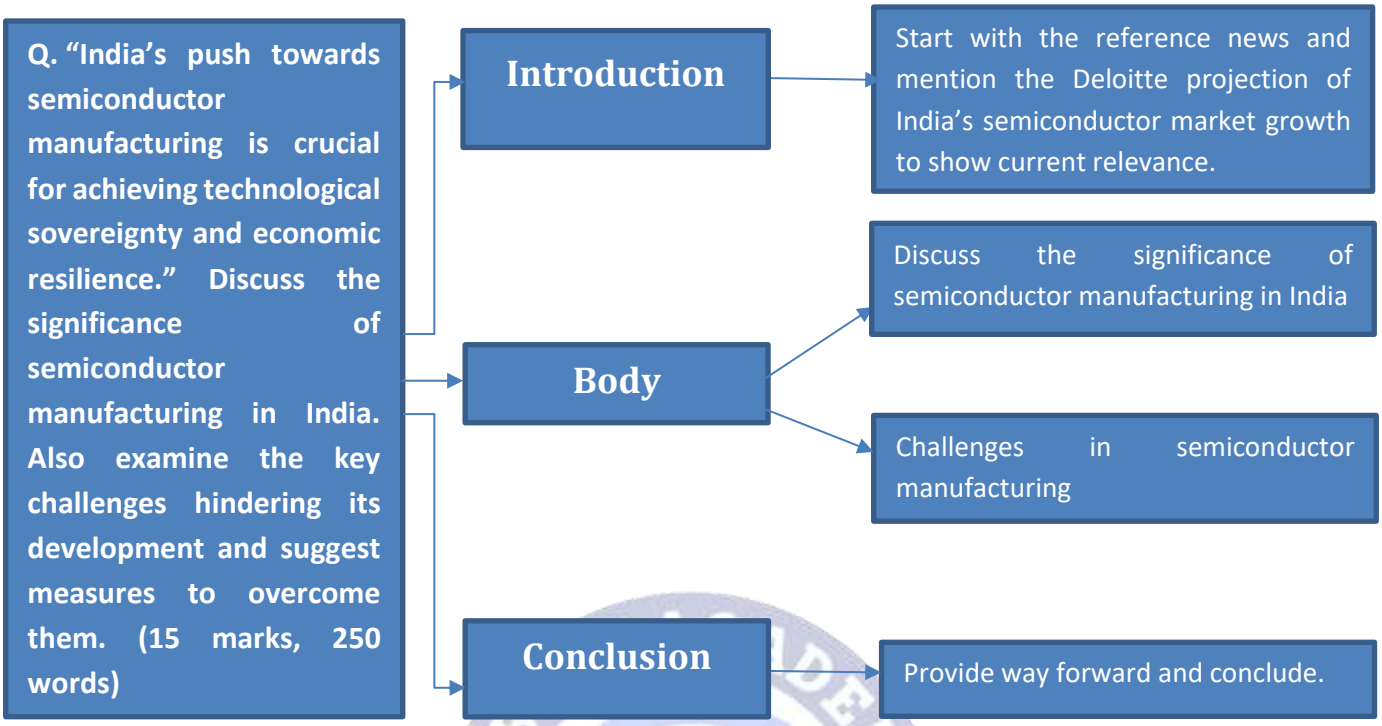
CONCLUSION:

- Semiconductor manufacturing is vital for India's economic growth, technological sovereignty, and strategic security. With sustained policy support, strong infrastructure, skilled manpower, and deeper ecosystem development, India can move from a chip-importing nation to a credible global semiconductor hub.

PRACTICE QUESTION:

Q. "India's push towards semiconductor manufacturing is crucial for achieving technological sovereignty and economic resilience." Discuss the significance of semiconductor manufacturing in India. Also examine the key challenges hindering its development and suggest measures to overcome them. (15 marks, 250 words)

APPROACH:



MODEL ANSWER:

According to a recent Deloitte report, India's semiconductor market is projected to grow from about $**45–50 billion in 2024–25 to $300 billion by 2035**, driven **by AI, automobiles, and data centres, highlighting its rising strategic importance.**

Significance of Semiconductor Manufacturing in India:

1. Supply Chain Resilience and Self-Reliance: Reducing over 90% import dependence strengthens resilience against global disruptions like COVID-19 and geopolitical tensions.

2. Strategic and National Security Importance: Semiconductors are critical for defence systems, telecom, and digital infrastructure, ensuring technological sovereignty.

3. Economic Growth and Investment Attraction: PLI and ISM incentives are attracting global players, boosting manufacturing and positioning India in global value chains.

4. Employment Generation: The sector can generate high-skilled jobs, leveraging India's demographic dividend and design expertise.

5. Boost to Innovation and R&D Ecosystem: Semiconductor manufacturing promotes advanced research in AI, electronics, and emerging technologies.

6. Industrial Diversification: Reduces dependence on traditional sectors and strengthens electronics manufacturing and Industry 4.0 capabilities.

Challenges in Semiconductor Manufacturing:

1. Capital Intensive Nature: Fab units require billions of dollars with high operational costs and long gestation periods.

2. Infrastructure Constraints: Unreliable power supply and high water requirements pose major challenges.

3. Weak Ecosystem and Import Dependence: Dependence on imported equipment, materials, and limited domestic fabrication ecosystem.

4. Talent and Skill Gap: Shortage of specialised skills in fabrication, photonics, and ATMP operations.

5. Policy and Regulatory Bottlenecks: Delays in approvals, land acquisition, and lack of coordination between Centre and states.

6. Global Competition: Strong competition from established hubs like Taiwan, South Korea, and China.

Way Forward:

1. Ensure policy stability and long-term funding: Move from short-term incentives to a sustained national semiconductor programme.

2. Develop robust infrastructure: Ensure reliable power, water, and semiconductor clusters with plug-and-play facilities.

3. Strengthen skill ecosystem: Promote industry-academia collaboration, specialised training, and fab-level exposure.

4. Deepen domestic ecosystem: Develop capabilities in materials, equipment, OSAT/ATMP, and design.

5. Fast-track clearances: Implement single-window mechanisms and improve Centre–State coordination.

6. Promote global partnerships: Encourage technology transfer, joint ventures, and integration into global value chains.

Government initiatives such as the **India Semiconductor Mission (ISM), Semicon India Programme, PLI Scheme, and Design Linked Incentive (DLI)** reflect India's strong policy push in this sector. With effective execution, infrastructure development, and ecosystem deepening, India can transition from a semiconductor importer to a globally competitive manufacturing hub, ensuring long-term economic and strategic gains.