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India's Semiconductor Mission Needs a Materials Mission

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If India wants to be a technology leader rather than a technology assembler, advanced materials and the raw inputs that go into them have to be treated as a strategic bet. This will yield returns beyond semiconductors. An example of the promise are the emerging uses of metal-halide perovskites.

Semiconductors lie behind nearly everything that runs on electricity today: phones, cars, hospital equipment, solar inverters, even the servers that train AI models. As economies grow more digital, the ability to design and make these chips is a measure of the strength of a country's technological base. India recognised this in December 2021, when the government launched the India Semiconductor Mission (ISM) with an incentive outlay of roughly $9.2 billion to build a domestic ecosystem for design, fabrication, packaging, and testing (India Semiconductor Mission, 2026). There is an urgency behind this push. India imported chips, integrated circuits, memory devices and related components worth close to $20.6 billion in FY 2023-24, over 18% more than the year before.

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In the five years since the launch of the mission, 12 manufacturing projects have been cleared, with a cumulative investment pipeline of about Rs 1.64 lakh crore, and three units, Micron, Kaynes and CG Semi, are already in commercial production (India Brand Equity Foundation, 2026). This is no small achievement for a country which, until recently, made almost none of the chips it uses.

In July 2026, the union cabinet cleared the second phase: Semicon 2.0 with an outlay of Rs 1.27 lakh crore, ($13.2 billion in current exchange rates or around 45% more than the first) though it is what the money is to be spent on that deserves attention. Semiconductor equipment, chemicals, gases and materials now attract a flat 30% incentive, and the mission describes its own purpose as ecosystem development rather than chip design and manufacturing alone (APAC News Network, 2026; India Semiconductor Mission, 2026). This is, in effect, an official acknowledgement of something researchers have been saying for a while: a mission built only around fabrication plants was always going to be an incomplete one. A fab runs on ultra-pure chemicals and on speciality gases that process wafers and deposit layers a few atoms thick. India already has a large speciality-chemicals industry that could move into supplying them. Whether this new acknowledgement is backed by actual spending on laboratories, real-time testing and into pilot lines will decide how much this second phase really changes.

Promise of Perovskites

Manufacturing capacity is important, but it is, only one layer of a much bigger innovation system. Silicon reshaped electronics because the material itself opened up possibilities that no amount of factory-building could have produced. Silicon carbide (SiC) and gallium nitride (GaN) are now reshaping the automotive industry, and advance opto-electronics such as in the display industry, while gallium arsenide (GaAs) and indium phosphide (InP) serve communications, and data transmission. Among the materials still finding their industrial footing, metal-halide perovskites (MHPs) are the most important and emerging, precisely because their supply chains and manufacturing base are still being decided. MHPs are a family of crystalline compounds whose composition can be tuned in many directions, and that is where their value lies. Change the chemistry a little and the material shifts from harvesting sunlight in a solar cell to detecting X-rays in a sensor or emitting light in an LED. That versatility has made them one of the fastest-moving areas in materials research.

Among all the promising applications and current research developments, solar cells are the most obvious example of that pace of change. Perovskite cell efficiency has climbed from under 4% in 2009 to more than 27% today, a leap during a little over 15 years, against the several decades silicon needed to reach comparable numbers (National Laboratory of the Rockies). Perovskite-silicon tandem cells, in which each material captures a different part of the spectrum, have already passed 34% efficiency in the laboratory, more than silicon manages on its own.

The silicon ecosystem is dominated by established players in Taiwan, South Korea, the United States, Japan and China. The industrial landscape around perovskites is different. Late entrants can get an opening: competing by creating value earlier in the chain through new materials discovery, innovative device architecture and sustainable workflow optimization, among others, rather than merely building more factories.

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India, in that sense, has had a decent start. Research groups at IIT Bombay, IIT Roorkee and IISc Bengaluru, along with public institutions such as CSIR-NPL and ARCI Hyderabad, are working on perovskite materials, tandem devices, stability testing and scale-up (CSIR-National Physical Laboratory; International Advanced Research Centre for Powder Metallurgy and New Materials). A small start-up ecosystem has grown alongside them. ART-PV India, incubated at IIT Bombay's National Centre for Photovoltaic Research and Education (NCPRE), has demonstrated a two-terminal silicon-perovskite tandem cell at 29.8% efficiency and is building a $10 million fabrication facility on campus with support from the Ministry of New and Renewable Energy and licensing partnerships with First Solar and Waaree (Perovskite-Info). P3C Technology and Solutions, a spin-off from IIT (BHU) Varanasi, is running a pilot line and has had its modules reliability-tested at the National Institute of Solar Energy (PV magazine, 2025). Others, including ABX3 PV and IIT Roorkee-incubated Perovskite Innovations, are working on lightweight modules and solar windows. While this is a real base, it also remains thin and scattered.

Other countries are already past the lab stage. Oxford PV in the UK began commercial sales of perovskite tandem panels in 2024. Japan has backed Sekisui Chemical with close to $1 billion in support, targeting 1 GW of production by 2030. In China, BOE has produced a pilot-line sample over two metres long at above 20% cell efficiency, pushing perovskite photovoltaics toward industrial scale. The lesson for India here is that research, on its own, does not build an industry. Each of these countries paired scientific capability with pilot lines that could grow into full manufacturing, with the means to test devices in real conditions. They also had companies willing to absorb the cost and risk of scaling up.

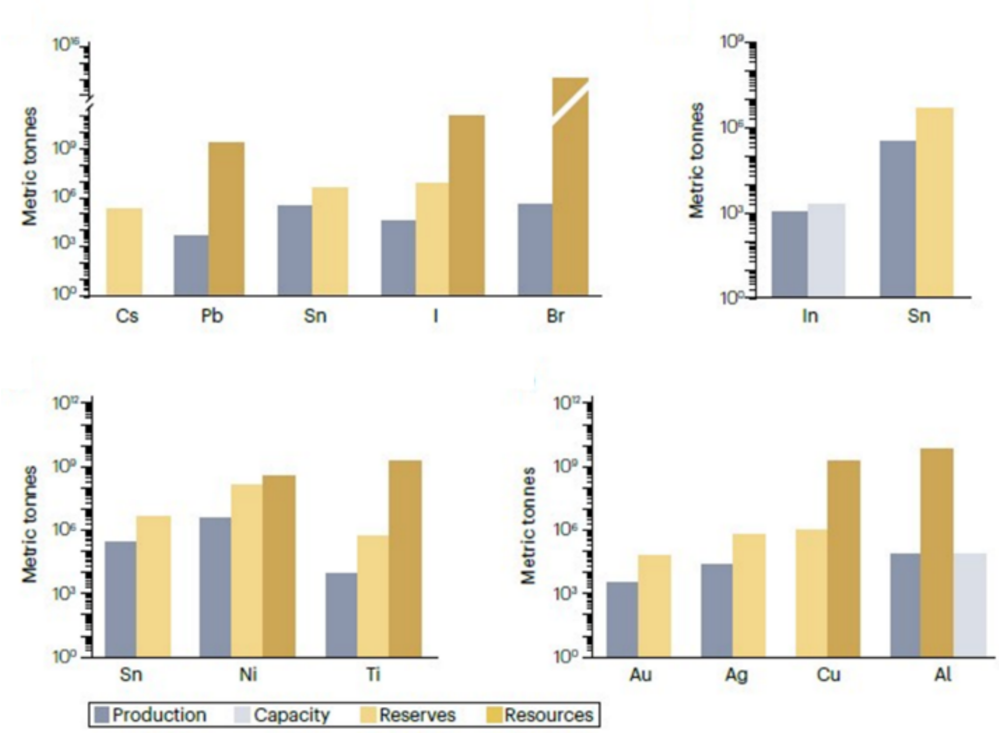
The opportunity extends well beyond solar industry. MHP-based X-ray detectors are being tested for medical imaging, and if the technology matures, India could make its own detector components instead of importing them, which would help its electronics base and its healthcare manufacturing at the same time.

Perovskite photodetectors respond across the optical spectrum and are therefore useful for digital imaging and biomedical monitoring while also being explored for optical communication (Li et al., 2020; Oyola-Torres et al., 2026), whereas Perovskite-based LEDs and displays are being widely researched globally on a similar scale. For an emerging economy like India, these applications matter because they extend the opportunity beyond solar manufacturing. Sensing, imaging and lighting are established fields with a broad range of products and can offer more value than solar module assembly.

Supply Chain

Building on its strengths in materials research and electronics, India could use these emerging technologies to set a broader scientific and industrial ambition for the next decade. However, these opportunities come with their own challenges. Many high-performing perovskite formulations still depend on lead, with the attendant problems in handling and disposal. While lead-free chemistries exist, they remain well behind on efficiency. Heat and humidity continue to degrade devices outside controlled conditions, and commercial guarantees on perovskite panels fall short of the 25-year warranties silicon manufacturers routinely offer. While India has experience in regulating solar modules and managing electronic waste, that experience will have to be extended to the specific risks perovskites bring. Furthermore, while these are device-level problems that are at least being worked on, there is an upstream question: whether the raw materials behind perovskites can be secured at scale.

Figure 1: Global Availability of Elements used in Perovskite Technologies



The picture in Figure 1 is more mixed than alarming. Resources of tin, bromine and iodine are far larger than current annual production, so availability is not the immediate constraint. The more immediate issue is the concentration of supply. China alone accounts for about 70% of the world's refined indium (U.S. Geological Survey, 2025b). Indium production is also closer to its reserve base than that of the other elements shown in Figure. Because indium is recovered as a by-product of zinc refining, output cannot rise quickly when demand increases. For example, a decade ago, touchscreen demand for indium tin oxide exceeded supply and prices moved sharply (Werner et al., 2015). On the other hand, caesium, used in the more stable formulations, comes from a handful of sites worldwide (U.S. Geological Survey, 2025a). This is a supply risk even though the volumes needed per cell are small.

The problem extends beyond perovskites. Conventional and compound-semiconductor manufacturing depends on high-purity silicon, gallium and germanium, alongside the ultra-pure chemicals and speciality gases used throughout fabrication. In 2023, China imposed export controls on both gallium and germanium (Mayer Brown, 2023). The episode showed the kind of supply-chain risk that arises when a critical input is produced in a small number of countries. As India increases manufacturing under the ISM, securing supply of these upstream inputs is as important as building the fabs. Otherwise, the country will be simply exchanging dependence on imported chips for dependence on imported materials.

The National Critical Mineral Mission (NCMM), approved in January 2025 with an outlay of Rs 34,300 crore over seven years, covers the entire process from exploration of potential minerals to mining, usable processing and recovery from end-of-life products, and its list of 30 critical minerals include indium, tin, silicon, gallium and germanium (Press Information Bureau, 2025). It does not include iodine, bromine or caesium. Those are the halides and cations that make a perovskite a perovskite, and India produces none of them at scale. World output of iodine is dominated by Chile and Japan. India has no meaningful domestic production of iodine, and it is already among the three largest consumers globally (U.S. Geological Survey, 2025). Tin resources have been identified in Chhattisgarh, Odisha and Haryana, but domestic production remains negligible. Folding perovskite-relevant elements into the NCMM's scope is a small administrative step to take, and it costs considerably less to deal with a supply constraint in advance than fixing it after a plant has been commissioned.

From Lab to Manufacturing

Securing materials is dealing with one half of the problem. The other challenge is India's difficulty in turning laboratory results into manufacturable technology. Some of the infrastructure exists. The MeitY-supported INUP programme gives researchers and start-ups access to shared nanofabrication and characterisation facilities (Indian Nanoelectronics Users Programme), the Semiconductor Laboratory at Mohali handles the conventional semiconductor flow from fabrication, to packaging and final testing, and the National Institute of

Solar Energy already performs module reliability testing. However, what is missing is pilot-scale capacity, which can validate new materials and processes under conditions closer to a factory than a university laboratory. Taiwan's Industrial Technology Research Institute (ITRI) and Belgium's IMEC are models -- sitting between academia and industry, offering shared facilities where processes and equipment can be proven before a company commits to full-scale production.

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There is a coordination problem as well that needs to be fixed. Perovskite work in India today sits across MNRE-funded solar programmes at NCPRE, MeitY's semiconductor and nanoelectronics schemes, DST-funded materials science departments and CSIR laboratories, largely working apart from each other and often duplicating equipment and testing protocols. Shared pilot lines for scale-up, module assembly, reliability or stress testing and final quality control would do more to move things forward than what any single new laboratory can do.

ISM 2.0's explicit mention of materials is an important signal, and it deserves to be read as more than providing a bigger budget for the same plan. Whether it works will come down to how the money is actually spent: on shared testing infrastructure, on pilot lines that can be a bridge between the lab and the factory floor, as well as securing the mineral inputs before they become a bottleneck. Every transformation in the semiconductor industry has come from new materials that made possible devices nobody could build before. Perovskites are just one example, but demonstrate a much larger opportunity.

India has to decide if it will settle for manufacturing what other countries have already invented, or if it wants to put its weight behind the science that determines what gets invented next, and behind the unglamorous supply-chain work that makes that science usable at scale. If India wants to be a technology leader rather than a technology assembler, advanced materials and the raw inputs that go into them have to be treated as a strategic bet, which will surely yield returns beyond semiconductors.

The views expressed are personal.

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