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Semiconductor Devices: Physics and Technology, Third Edition is an introduction to the physical principles of modern semiconductor devices and their advanced fabrication technology. It begins with a brief historical review of major devices and key technologies and is then divided into three sections: semiconductor material properties.

These detectors were somewhat troublesome, however, requiring the operator to move a small tungsten filament the whisker around the surface of a galena lead sulfide or carborundum silicon carbide crystal until it suddenly started working. At the time their operation was completely mysterious. Metal rectifier Another early type of semiconductor device is the metal rectifier in which the semiconductor is copper oxide or selenium. Westinghouse Electric was a major manufacturer of these rectifiers. World War II[edit] During World War II, radar research quickly pushed radar receivers to operate at ever higher frequencies and the traditional tube based radio receivers no longer worked well. The introduction of the cavity magnetron from Britain to the United States in during the Tizard Mission resulted in a pressing need for a practical high-frequency amplifier. By this point they had not been in use for a number of years, and no one at the labs had one. After hunting one down at a used radio store in Manhattan , he found that it worked much better than tube-based systems. He spent most of trying to grow more pure versions of the crystals. He soon found that with higher quality crystals their finicky behaviour went away, but so did their ability to operate as a radio detector. One day he found one of his purest crystals nevertheless worked well, and it had a clearly visible crack near the middle. However as he moved about the room trying to test it, the detector would mysteriously work, and then stop again. After some study he found that the behaviour was controlled by the light in the roomâ€”more light caused more conductance in the crystal. He invited several other people to see this crystal, and Walter Brattain immediately realized there was some sort of junction at the crack. Further research cleared up the remaining mystery. The crystal had cracked because either side contained very slightly different amounts of the impurities Ohl could not removeâ€”about 0. One side of the crystal had impurities that added extra electrons the carriers of electric current and made it a "conductor". The other had impurities that wanted to bind to these electrons, making it what he called an "insulator". Because the two parts of the crystal were in contact with each other, the electrons could be pushed out of the conductive side which had extra electrons soon to be known as the emitter and replaced by new ones being provided from a battery, for instance where they would flow into the insulating portion and be collected by the whisker filament named the collector. However, when the voltage was reversed the electrons being pushed into the collector would quickly fill up the "holes" the electron-needy impurities , and conduction would stop almost instantly. This junction of the two crystals or parts of one crystal created a solid-state diode, and the concept soon became known as semiconduction. The mechanism of action when the diode is off has to do with the separation of charge carriers around the junction. This is called a " depletion region ". Development of the diode[edit] Armed with the knowledge of how these new diodes worked, a vigorous effort began to learn how to build them on demand. Within a year germanium production had been perfected to the point where military-grade diodes were being used in most radar sets. Development of the transistor[edit] Main article: History of the transistor After the war, William Shockley decided to attempt the building of a triode -like semiconductor device. He secured funding and lab space, and went to work on the problem with Brattain and John Bardeen. The key to the development of the transistor was the further understanding of the process of the electron mobility in a semiconductor. It was realized that if there were some way to control the flow of the electrons from the emitter to the collector of this newly discovered diode, an amplifier could be built. For instance, if contacts are placed on both sides of a single type of crystal, current will not flow between them through the crystal. However if a third contact could then "inject" electrons or holes into the material, current would flow. Actually doing this appeared to be very difficult. If the crystal were of any reasonable size, the number of electrons or holes required to be injected would have to be very large, making it less than useful as an amplifier because it would require a large injection current to start with. That said, the whole idea of the crystal diode was that the crystal itself could provide the electrons over a very small distance, the depletion region. The key appeared to be to place the input and output contacts very close together on the surface of the crystal on either side of this region. Brattain started working on building such a device, and tantalizing hints of amplification continued to appear as the team worked on the problem. Sometimes the system would work but then stop working unexpectedly. In one instance a non-working system started working when placed in water. Ohl and Brattain eventually developed a new branch of quantum mechanics , which became known as surface physics , to account for the behaviour. The electrons in any one piece of the crystal would migrate about due to nearby charges. Electrons in the emitters, or the "holes" in the collectors, would cluster at the surface of the crystal where they could find their opposite charge "floating around" in the air or water. Yet they could be pushed away from the surface with the application of a small amount of charge from any other location on the crystal. Instead of needing a large supply of injected electrons, a very small number in the right place on the crystal would accomplish the same thing. Their understanding solved the problem of needing a very small control area to some degree. Instead of needing two separate semiconductors connected by a common, but tiny, region, a single larger surface would serve. The electron-emitting and collecting leads would both be placed very close together on the top, with the control lead placed on the base of the crystal. When current flowed through this "base" lead, the electrons or holes would be pushed out, across the block of semiconductor, and collect on the far surface. As long as the emitter and collector were very close together, this should allow enough electrons or holes between them to allow conduction to start. The first transistor[edit] A stylized replica of the first transistor The Bell team made many attempts to build such a system with various tools, but generally failed. Eventually they had a practical breakthrough. A piece of gold foil was glued to the edge of a plastic wedge, and then the foil was sliced with a razor at the tip of the triangle. The result was two very closely spaced contacts of gold. When the wedge was pushed down onto the surface of a crystal and voltage applied to the other side on the base of the crystal , current started to flow from one contact to the other as the base voltage pushed the electrons away from the base towards the other side near the contacts. The point-contact transistor had been invented. What is now known as the " pâ€”nâ€”p point-contact germanium transistor " operated as a speech amplifier with a power gain of 18 in that trial. Origin of the term "transistor"[edit] Bell Telephone Laboratories needed a generic name for their new invention: Pierce , won an internal ballot. This is an abbreviated combination of the words "transconductance" or "transfer", and "varistor". The device logically belongs in the varistor family, and has the transconductance or transfer impedance of a device having gain, so that this combination is descriptive. Improvements in transistor design[edit] Shockley was upset about the device being credited to Brattain and Bardeen, who he felt had built it "behind his back" to take the glory. Shockley was incensed, and decided to demonstrate who was the real brains of the operation. This structure went on to be used for the vast majority of all transistors into the s, and evolved into the bipolar junction transistor. With the fragility problems solved, a remaining problem was purity. Making germanium of the required purity was proving to be a serious problem, and limited the yield of transistors that actually worked from a given batch of material. Scientists theorized that silicon would be easier to fabricate, but few investigated this possibility. Teal was the first to develop a working silicon transistor, and his company, the nascent Texas Instruments , profited from its technological edge. From the late s most transistors were silicon-based. Within a few years transistor-based products, most notably easily portable radios, were appearing on the market. The static induction transistor , the first high frequency transistor, was invented by Japanese engineers Jun-ichi Nishizawa and Y.

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