
بسم الله الرحمن الرحيم

Contents(فهرست)

0.1.2 Major Semiconductor Devices

❖Some major semiconductor devices are listed in Table1 in chronological(زمانی) order; those with a superscript(بالانویس) *b* are two-terminal devices, and the others are three-terminal or four-terminal devices.

❖ The earliest systematic study of semiconductor devices (metal-semiconductor contacts) is generally attributed to Braun, who in 1874 discovered that the resistance of contacts between metals and metal sulfides (e.g., copper pyrite($CuFeS_2$)) depended on the magnitude and polarity of the applied voltage.

❖Figure 3 shows the first transistor.

TABLE 1 Major Semiconductor Devices

Year	Semiconductor Device[a]	Author(s)/Inventor(s)	Ref.
1874	Metal-semiconductor contact[b]	Braun	5
1907	Light emitting diode[b]	Round	6
1947	Bipolar transistor	Bardeen, Brattain, and Shockley	7
1949	*p–n* junction[b]	Shockley	8
1952	Thyristor	Ebers	9
1954	Solar cell[b]	Chapin, Fuller, and Pearson	10
1957	Heterojunction bipolar transistor	Kroemer	11
1958	Tunnel diode[b]	Esaki	12
1960	MOSFET	Kahng and Atalla	13
1962	Laser[b]	Hall et al.	15
1963	Heterostructure laser[b]	Kroemer, Alferov and Kazarinov	16,17
1963	Transferred-electron diode[b]	Gunn	18
1965	IMPATT diode[b]	Johnston, DeLoach, and Cohen	19
1966	MESFET	Mead	20
1967	Nonvolatile semiconductor memory	Kahng and Sze	21
1970	Charge-coupled device	Boyle and Smith	23
1974	Resonant tunneling diode[b]	Chang, Esaki, and Tsu	24
1980	MODFET	Mimura et al.	25
2004	5 nm MOSFET	Yang et al.	14

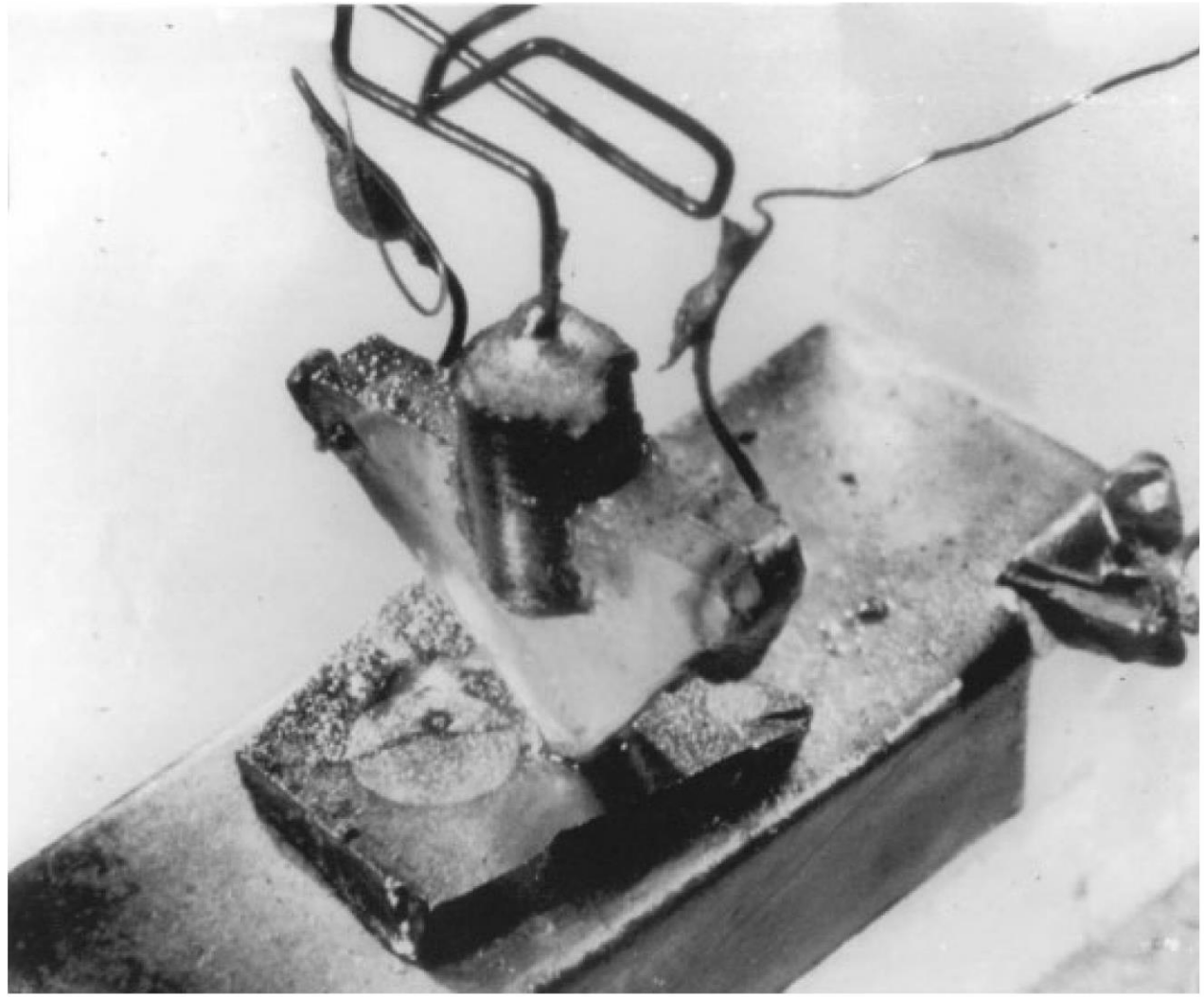

Fig. 3 The first transistor.[7] (Photograph courtesy of Bell Laboratories, Alcatel-Lucent Co)

0.2.2 Technology Trends

- Since the beginning of the microelectronics era(عصر), the smallest line width or the minimum feature length(طول مشخصه) of an integrated circuit has been reduced at a rate of about 13% per year. At that rate, the minimum feature length will shrink(کوچک شدن) to about 10 nm in the year 2020.

- Figure 8 shows the minimum feature length versus year of first production from 1978 to 2010 and projected to 2020.

- In 2002 we entered the nanoelectronics era by reducing the minimum feature length below 100 nm.

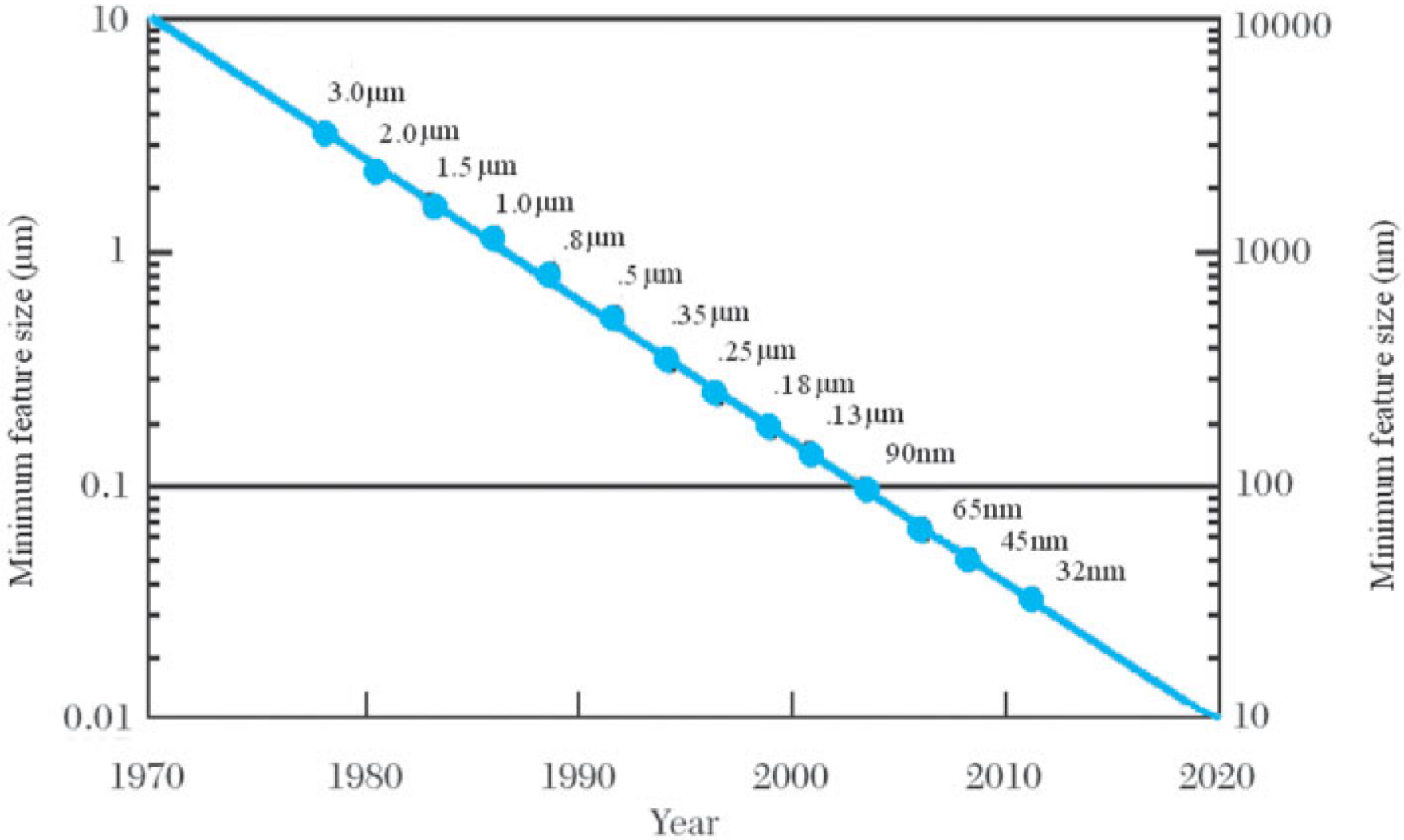

Fig. 8 Exponential decrease of the minimum feature length versus time.[52]

❖Device miniaturization results in(...منجر می شود به) reduced unit cost per circuit function. For example, the cost per bit of memory chips has halved(نصف) every two years for successive generations(نسلهای متوالی) of DRAMs.

❖ As device dimension decreases, the intrinsic switching time also decreases: device speed has improved by five orders of magnitude since 1959. Higher speeds lead to expanded IC functional.

❖In the future, digital ICs will be able to perform data processing and numerical computation at terabit-per-second rates.

- As devices become smaller, they consume less power. Therefore, device miniaturization also reduces the energy used for each switching operation.
- The energy dissipated(تلف شده) per logic gate has decreased by over ten million times since 1959.
- Figure 9 shows the exponential increase in the actual memory density versus year of first production over the past 30 years.
- We note that the DRAM density increased by a factor of 2 every 18 months from 1978 to 2000.

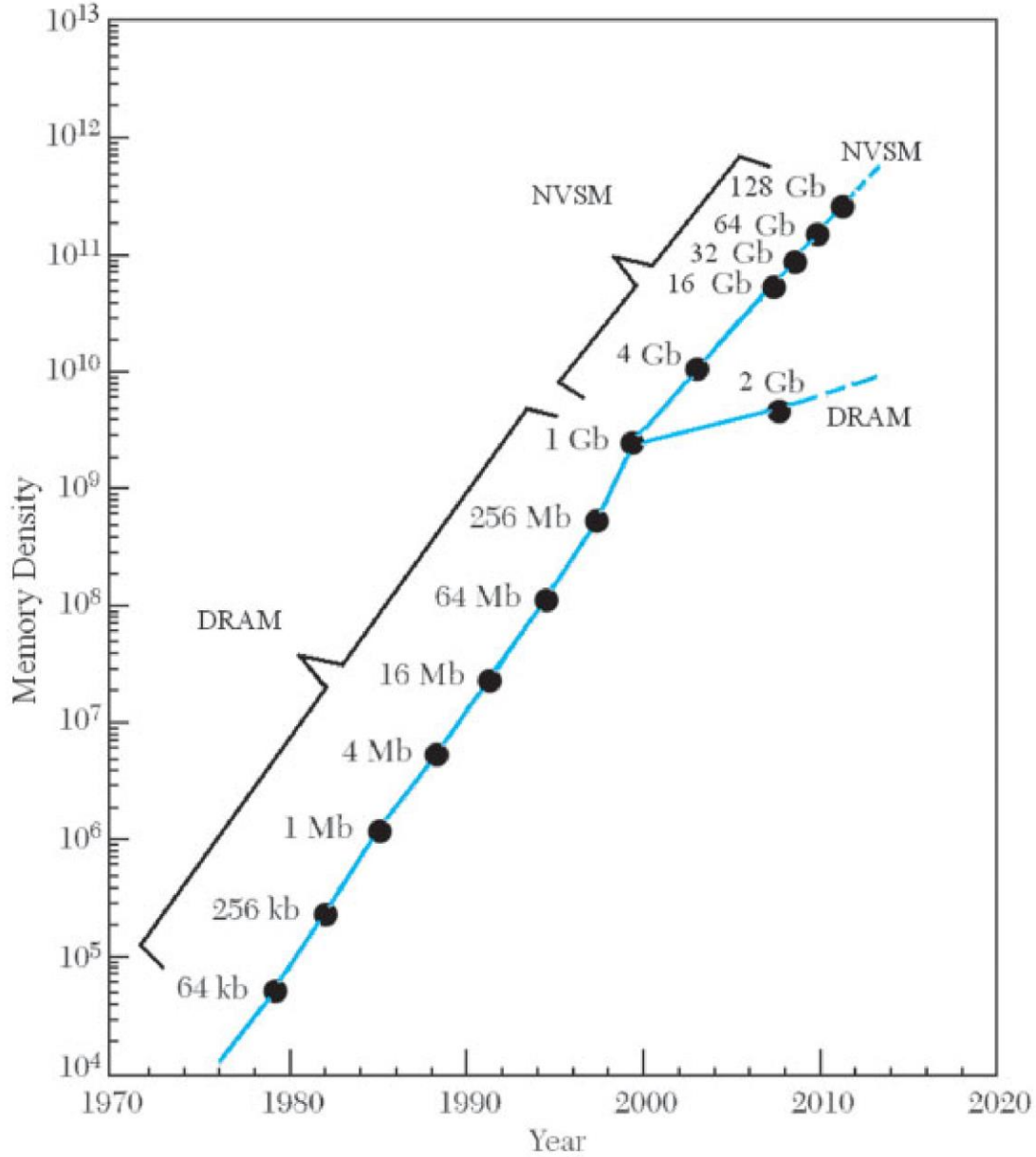

Fig. 9 Exponential increase in dynamic random access memory (DRAM) density and nonvolatile semiconductor memory (NVSM) density versus year.[52]

- After 2000, the growth rate of DRAM density slowed down considerably. On the other hand, NVSM density has continued the original growth rate of DRAM density, i.e., doubling every 18 months.

- If the trends continue, we expect that NVSM density will increase to 1000 Gb or 1 terabits (10^{12} bits) around 2015.

0.2 SEMICONDUCTOR TECHNOLOGY

- Although the field of semiconductor devices is a relatively new area of study, it has had enormous impact on our society and the global economy. This is because semiconductor devices are the foundation of the largest industry in the world—the electronics industry.

- This introductory chapter has presented a historical review of major semiconductor devices from the first study of metal-semiconductor contact in 1874 to the fabrication of an ultrasmall 5-nm MOSFET in 2004.

- Of particular importance(آنچه از اهمیت ویژه برخوردار است...) are the invention of the bipolar transistor in 1947, which was the beginning of the modern electronic era; the development in 1960 of the MOSFET, the most important device for integrated circuits; and the invention of the nonvolalite semiconductor memory in 1967, which has been the technology driver(موتور) of the electronic industry since 1990.

- We have also described key semiconductor technologies.

- Of particular importance are the development of the lithographic photoresist in 1957, which established the basic pattern-transfer process for semiconductor devices;
- the invention of the integrated circuits in 1959, which was seminal(اصلی) to the rapid growth of the microelectronic industry; and the developments of the DRAM in 1967 and the microprocessor in 1971, which constitute the two largest segments(بخش) of the semiconductor industry.
- There is a vast literature on semiconductor-device physics and technology. To date, more than 500,000 papers have been published in this field.

- In this book, each chapter deals with a major device or a key technology.
- Each is presented in a clear and coherent(منسجم) fashion without heavy reliance(اتكا) on the original literature.
- However, we have selected a few important papers at the end of each chapter for reference and for further reading.