Geopolitics of semiconductors: the parallel lives of silicon in integrated circuits and in PV cells

Alessandro Paccagnella

Department of Information Engineering, University of Padova, via Gradenigo 6/b, 35131 Padova, Italy

Keywords: *microelectronics, PV, geopolitics.*

Abstract:

Semiconductors have been and are the fundamental materials for the development of microelectronics and photovoltaics (PV). While the first transistors (Bell labs, 1947) were fabricated on Ge, Si appeared as the material of choice for PV since the first publication (Bell labs, 1954) on its conversion properties of solar radiation into electrical power; only in the 50s Si gradually started replacing Ge for the production of discrete transistors. In both PV and microelectronics, the space race – i.e., governmental agencies and funds - gave a substantial support to the development of the underlying semiconductor technologies, for both civil and military applications in the US and in the USSR.

A decoupling between government driven applications and commercial market appeared first in the Western bloc in the 50s: the mass production of transistors started, thanks to the success worldwide of applications such as the transistor-based portable radio, which sold millions of units in few years. Volume production led to a decrease of the per-unit cost and consequently to further enlargement of the market, where Japanese industries played a leading role, thus tracing a first shift of semiconductor production from the US to the Asia-Pacific. On the other hand, the cost of solar cells remained very high, limiting its diffusion to niche applications where cost was not an issue, i.e., space missions.

The invention of the integrated circuit (IC: on germanium, Texas Instruments, 1958) and its coupling to the silicon planar process (Fairchild, 1959) opened the door to the exponential growth of the US IC industry, as testified by the first formulation of Moore's law (1965), later consolidated (1975) in the well-known statement that the number of transistors in a single (silicon) chip doubles every two years. Even in this case, the US governmental support was instrumental to grant adequate support to this innovative technology, whose early adoption in commercial products was challenging: in fact, the NASA Apollo project was the largest single consumer of ICs in the period 1961-1965.

The driving force behind the exponential growth of the transistor density on a chip was the MOS technology, which made (and still makes) Si the semiconductor of choice for microelectronics, thanks to the quality of the thermal oxide SiO_2 that can be grown in strictly controlled ways on its surface. MOS ICs started to appear at the beginning of the 70s and surpassed the bipolar-based ICs by the end of that decade, in terms of annual sales.

In the same decade, the first energy shock hit the world due to the oil embargo from Arab countries following the Yom Kippur war with Israel (1973), driving a conspicuous effort to find alternative and renewable energy sources: first of all, PV. The relentless research on materials and technology led to a constant increase of the cell efficiency over the years, thanks to the introduction of new architectures and new materials, that drove a substantial decrease of the cost per watt of the installed panels. Yet, it was a political decision by the German government at the beginning of this century – a strong economic incentive to install solar panels - that gave a big push to the growth of the PV industry: increasing mass production has been accompanied by the exponential decrease of the panel cost to the final user, now dominated by the crystalline Si technology.

In this century both microelectronics and PV have seen a substantial displacement of the productive sites from Western countries to the Asia-Pacific region, where China plays a growing industrial role following specific guidelines and objectives issued at the central political level, in particular under President Xi, in strong contrast with Western governments that have neglected semiconductors policies for several years, thus losing large part of the market shares they were holding at the beginning of the century. After the covid-19 pandemic the US and Europe governments have become aware of the strategic relevance of semiconductors and they are trying to re-shore at least part of the supply chains following various political approaches and results, which we may find almost every day on the media.