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Electronics: A Potted History and a Glimpse of the Future

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ABSTRACT

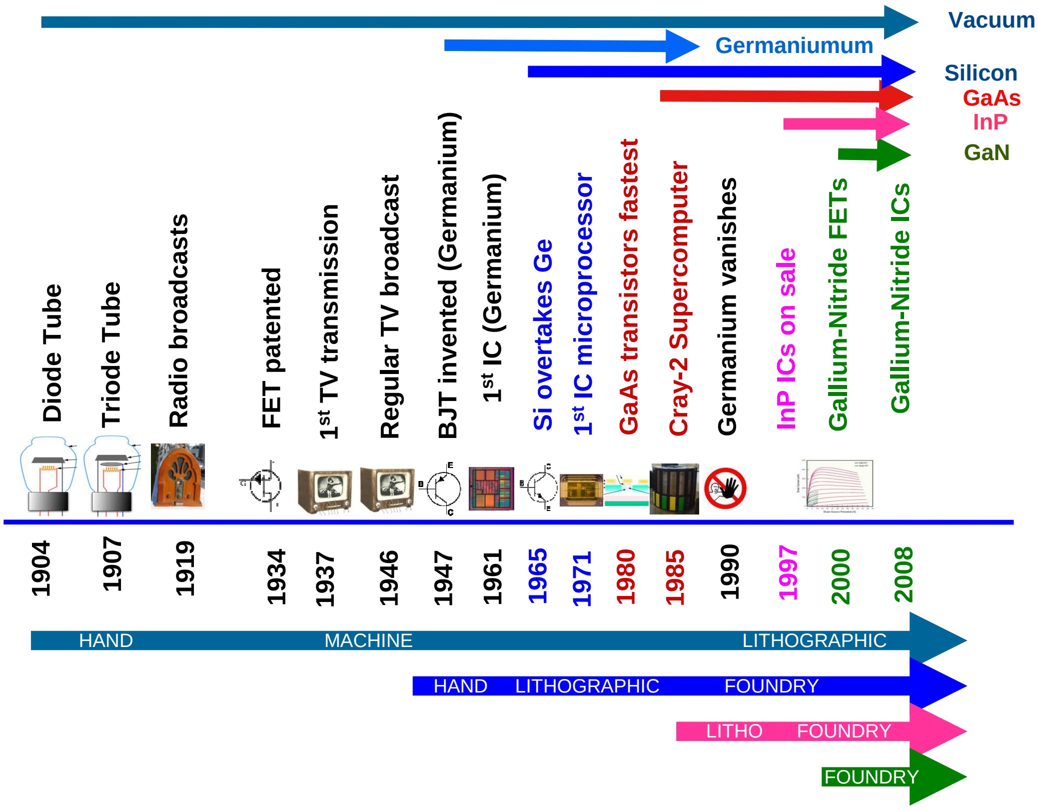
Even electronics people are surprised to learn that the vacuum device industry is still a thriving US$1B business. The tube presided over the electronics revolution, including the fastest-ever penetration of a technology into society—that is the arrival of broadcast radio in the 1920s, not the cellphone in the 1990s—but the vacuum tube also remains far ahead of solid-state alternatives in power-bandwidth. Electronics people are often surprised to learn that Silicon, as a technology for transistors, is superior only in price (and volume). It was not the first solid-state vehicle, Germanium was. It is not the fastest, the so-called III-V family of Gallium-Arsenide and Indium-Phosphide is. Cray supercomputers had a heart of GaAs. In fact, compound semiconductors (CS) in the form of GaAs enabled satellite communications, satellite TV, LEDs, radar, and fibre-optics. It is only recently that pure-silicon cellphones and TV dishes appeared. Hold a complex cellphone in your hand and you hold over half the elements of the periodic table. Most high-performance electronics relies on CS ICs, GaAs, InP, GaN, SiGe.

Looking at the history another way, transistors appeal because they can be manufactured lithographically, in Silicon for less than 1 millionth of $1, RRP. That requires a huge capital investment. In the 1960s & 1970s famous companies built fabs and sold ICs and some became very rich. Fabs that did not sell enough volume folded; in Australia that was AWA through to Peregrine. Will Sapphicon/Silanna change that? In the 1980s & 1990s the industry went largely "fabless", and foundries/fabs made ICs for many customers, protecting their IP, sharing costs. Except for some huge customers, most CS fabs are "pure play". It is the same in silicon, with more "captive", large-volume fabs such as Intel, NXP (Philips), Freescale (Motorola), etc. This fabless trend means that small players get access. In Sydney, Mimix is an example in the CS world. Modest-dimension silicon ICs can be fabricated for a few US$k, fine-dimension silicon or GaAs ICs for a few US$10k's. This really happened in the 1990s, so that the "noughties" are thought of as the fabless decade. Education in electronics involves knowing about all devices and how you make things out of them. It means knowing about ICs, not simply the latest silicon VLSI, but vacuum tubes, CS technologies, fab access, the whole "lay of the land" in electronics.

The latest CS technology to appear is Gallium-Nitride, or GaN. What does it offer? The speed of GaAs and an order of magnitude more power, and a few other properties that make it very tough and versatile. The second figure here compares two transistors of equal size and equal speed. The small green characteristic of the GaAs FET is that of a 100μm 25GHz-F_T GaAs MESFET, the best power III-V process available (circa 2003). The huge, red GaN FET characteristic dwarfs the GaAs one, yet was also that of a 100μm, 25GHz-F_T device, but in GaN not GaAs. GaN may displace some vacuum tubes, it could revolutionise medical in-vivo ablation techniques, it already has displaced some GaAs power amplifiers, and I believe it will eventually do to GaAs what Silicon did to Germanium.

I have a PhD student working on the automation of coffee roasting. Apart from being a subject that seems to interest just about everyone, it is a subject "whose time has come". Where once upon a time beans were roasted centrally and shipped across the country, there is a shift towards every coffee shop, and perhaps soon every house with a coffee maker, roasting its own beans, in the interest of ultimate freshness. A few hundred dollars buys you a roaster on Trademe, but it does not give you the expertise to roast well on varying-quality beans. That is a matter of expertise, human or, in our hope, artificial and automatic. There is a "sea change" in the coffee-roasting landscape.

New Zealand has a thriving electronics industry with a long history. The renowned Kiwi ingenuity fits in well with the creative, understanding-based aspects of electronics, a discipline that is both an art and a science. However, the face of electronics is changing with the passing decades. There comes a "sea change" in the electronics landscape. Increasingly the ingenuity and added value in electronics is shifting from circuits composed of discrete components to ICs. These ICs are routinely assembled on circuit boards and require much less ingenuity, and return less value. It is in the design of the ICs that the ingenuity lies, and also the potential for profit. The fabless design model, in silicon and CS, is the affordable entry for the ingenious designer to the electronic world of the future. "Affordable" is a relative term, but we talk of $100s discrete, $10k's fabless, but $1e8 for the 1970s captive model. If New Zealand does not manage to buy into this, the long history of a Kiwi electronics industry will go the way of Germanium. Tell your local funding agency, before the last train leaves the station.



Scaled FET Comparison