INSiAVA comes to light

The story of INSiAVA (injection-enhanced silicon in avalanche) started with a vision in the early 1990s. It is a story interwoven with foresight, flawless timing, a methodological approach to both business and research, and – above all – discipline.

The computer industry is faced with the so-called interconnect dilemma, a challenge that was predicted decades ago by the co-founder of Intel, Gordon Moore.

In its quest to solve the chip-to-chip interconnect problem, INSiAVA (Pty) Ltd, a privately owned company established by the University of Pretoria as the commercialisation vehicle of its silicon electroluminescent technology (the generation of light from an electrical current), recently achieved another critical milestone.

Farsighted thinking

As early as 1990, Prof Monuko du Plessis, Director of the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University of Pretoria, spearheaded CEFIM's research efforts to focus on optical communication as the way to solve the chip-to-chip and on-chip interconnect problem. This prophetic insight turned out to be immensely accurate in terms of the way in which the industry unfolded.

As a result, Prof Du Plessis focused CEFIM's research efforts on the generation of light in silicon, in particular. Why silicon? Because 99% of the world's computer chips are created in silicon. The US$100-billion industry, dominated by industry giants such as Intel, ST Microelectronics and Mitsubishi, is based on the production of silicon chips in extremely controlled, maximum-purity silicon wafer plants – operating under the most highly restrictive contamination requirements.

Grasping the implication of this, Prof Du Plessis purposefully steered the microelectronic research at the University of Pretoria towards light generation from silicon, as opposed to any other medium, in order to find synergies with the industry's existing mega-billion dollar investment in silicon plants.

The innovation race to solve the chip-to-chip interconnect dilemma continues within a chequered environment. So-called "breakthrough" technologies are announced almost on a daily basis that claim to turn around the interconnect problem.

However, INSiAVA's competitive and strategic advantage lies in the fact that most chip-to-chip interconnect "solutions" are not compatible with CMOS (complementary metal-oxide-semiconductor) standards, which means that they cannot be used in the industry's mega-billion dollar silicon-based plants.

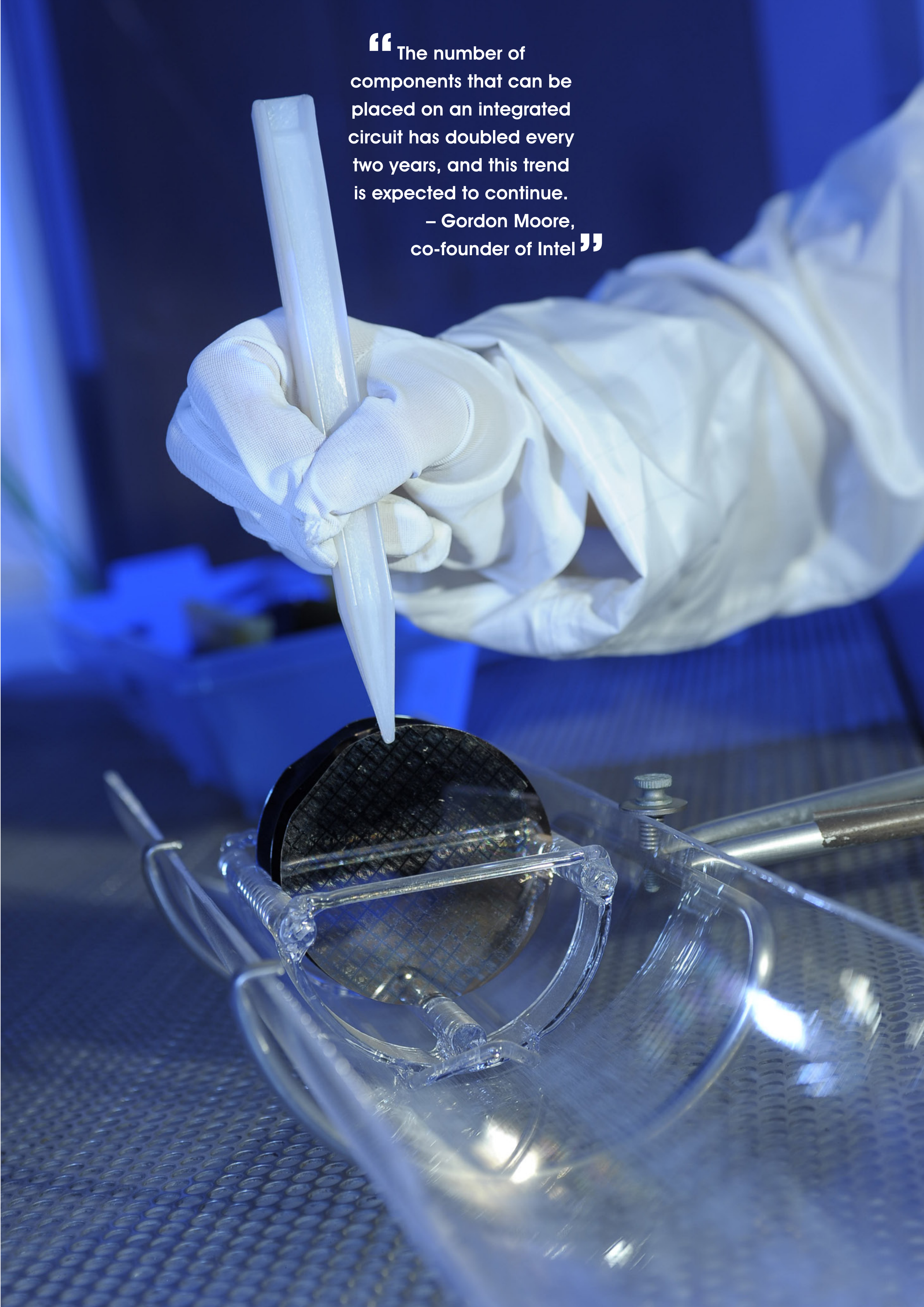
Prof Du Plessis' vision to use silicon-based optical technology is therefore one of the computing industry's potentially most sought-after new technologies.

A phased process

According to Gerrie Mostert, who is responsible for operationalising the start-up venture, INSiAVA (Pty) Ltd, and building its intellectual property (IP) portfolio, the project has been conducted in phases since it kicked off in the early 1990s.

A balance between the registration of international patents and the publication of more than 50 local and international peer-reviewed articles in accredited scientific journals has been a critical balancing act that the team has managed to achieve successfully.

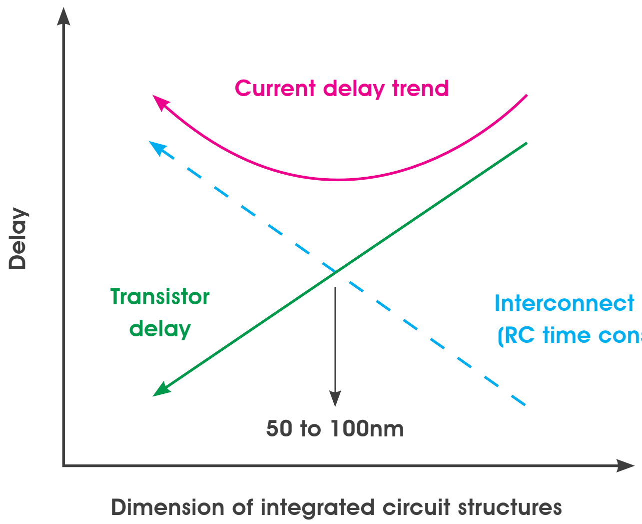
"In the process, publications were often delayed due to first patenting key aspects of the technology. Without the first two granted USA patents on the silicon light-emitting technology, no investor would have been interested in the technology. The discipline to delay publications and to file patents at the right time has been crucial in our journey thus far," says Mostert.



"The number of components that can be placed on an integrated circuit has doubled every two years, and this trend is expected to continue.

– Gordon Moore,
co-founder of Intel"

Moore's Law:
how it created the interconnect dilemma



→ 1. Moore's Law and circuit delay.

In 1965, Gordon E Moore, co-founder of Intel, noted that the number of transistors in integrated circuits has doubled every two years since the first integrated circuit was invented in 1958. He predicted that this trend was set to continue. This phenomenon is popularly known as Moore's Law. The driving forces behind Moore's Law were increased processing speed and increased functionality, while cost remained low by having it all available on a single chip. The interconnect lines (copper wires) between transistors on chips and between chips have become thinner, increasingly affecting the processing speed.

This reduction in size of the transistors and their interconnecting copper wires meant increased interconnect delays. When the transistor size reaches about 100 or 90 nanometer, the resulting delay is such that it offsets the gain of going smaller. This affects the reliability and overall performance of the circuit.

This phenomenon is widely known as "the interconnect dilemma".

One approach to resolve the interconnect dilemma is to communicate optically (by means of light) between and on computer chips instead of through metal wires.

Long-distance optical fibre communication is not a new technology. The challenge of long-distance optical data transfer was solved many years ago. The current challenge is to resolve this between and on computer chips. An economically viable solution to this challenge has been evading the computing industry for years.

To date, INSiAVA has filed patent applications for a suite of 12 different inventions, which all underpin vital breakthroughs and/or technological building blocks along the INSiAVA research path.

Phase I and Phase II of the project focused on creating and developing the silicon light source.

Phase III focused on making the silicon light source more efficient, while identifying a range of potential applications. It was underpinned by the key research objective to improve the external quantum efficiency of the light source from 0.01% to 0.1%. This objective was achieved in November 2009.

"Getting the power efficiency right remains a critical aspect and will continue to form the focus for the fourth phase of development," says Mostert. Power efficiency refers to the fraction of the electrical power input that converts to usable optical power output.

Phase IV is primarily aimed at improving the power efficiency, as well as commercialising the technology. It will culminate in the first niche applications once the technology meets industry specifications for each potential application.

"Research priorities include improving the power efficiency ratio by experimenting with device structure and device design, as well as integrated circuit design.

The development programme will also explore surface effects and a silicon germanium (Si-Ge) heterojunction as techniques to improve the power efficiency," notes Mostert.

The ultimate objective is to achieve a data transmission rate of 10 Gb/s (gigabits per second) within the next three years.

According to Mostert, the industry would not be able to ignore such transmission rates in a fully CMOS-compatible technology. “High-speed data communication is a killer application and will remain our highest priority for the next few years,” he says. “But there might also be other attractive applications that can be developed and commercialised in parallel by teams dedicated to those applications.”

The road to commercialisation

A paramount aspect of the commercialisation process is to consult and engage with industry to get advice on how to approach the research and development within the commercial requirements of the industry.

“With R3.6 million in our back pockets at the start of Phase II, we travelled overseas to meet with key role-players in the computer and venture capital industries to get advice on how to approach this project,” tells Mostert. This, coupled with Prof Du Plessis’ far-sighted vision to narrow down research efforts to silicon-based optical solutions in the early 1990s and the discipline of filing patent applications at the right time, made a significant difference to INSiAVA’s significant progress to date.

According to the August 2002 issue of *IEEE Spectrum*, the scientific journal of the International Institute of Electrical and Electronic Engineers, short-range optical data communication was likely to unfold as follows:

2002: computer to computer
2004–2007: board to board
2007–2012: chip to chip
2013: on-chip optical interconnects

The industry has fallen behind on the chip-to-chip solution due to the sheer technical challenge thereof. “After three to four years of lower budgets for research efforts, optical data transfer is regaining the interest of industry. There is a revitalised sense of urgency to find a chip-to-chip solution, not only promising research results,” says Mostert.

Phase IV of the research and the funding that has recently been secured mark the start of another exciting phase in INSiAVA’s history that will eventually solve the interconnect dilemma.

The solution for the chip-to-chip optical interconnect might come from South Africa – an achievement that would be remarkable by any standard. “We are at least a front-runner in the race,” concluded Mostert. “That, in itself, is already an achievement of note.”

Project profile

On 25 October 2010, the Chairperson of INSiAVA (Pty) Ltd, Prof Robin Crewe, announced the approval of a R30 million investment in the company over three years by its current shareholders, the University of Pretoria and the South African Intellectual Property Fund (SAIP Fund), managed by Triumph Venture Capital (Pty) Ltd. This marks the imminent launch of Phase IV of the development of the INSiAVA silicon-based light source technology. The project has proceeded according to the following course since 1990:

Phase I (1990–2004)

The University of Pretoria, with funding received from the Carl and Emily Fuchs Foundation, made a substantial investment of several million rand into the project.

Phase II (2004–2006)

The project received joint funding from the University of Pretoria and the Innovation Fund of the Department of Science and Technology.

Phase III (2007–2010)

The SAIP Fund invested R15 million in the project.

Phase IV (2011–2013)

An investment of R30 million over three years in INSiAVA (Pty) Ltd was approved by the shareholders, the SAIP Fund and the University of Pretoria, in October 2010.