

**VITALY PODZOROV'S** lab is decked with transparent boxes containing brightly coloured crystals hovering on hair-fine silver wires. Each is a transistor, similar to the ones that switch current in the circuits of every computer. The difference is that they are not made of silicon but organic materials – crystals of hydrocarbons, in fact. And their path from idea to reality could not be stranger.

Four years ago, a Bell Labs physicist was dazzling his peers with his work on electronic devices using organic crystals. At the height of his career, Hendrik Schön was publishing results at the remarkable rate of once every 8 days. Then it all collapsed in scandal.

When other researchers found they were unable to reproduce his results, Schön's work eventually came under intense scrutiny. An investigation revealed that Schön had fabricated the results in around a dozen papers. He was fired, and the field of organic electronics seemed to be in tatters. But it wasn't.

While some were keen to airbrush Schön out of history, a few determined researchers refused to give up: Schön's work had fired their imagination. "The work in my lab was inspired by Schön," says Mike Gershenson, who runs the lab where Podzorov works at Rutgers University in Piscataway, New Jersey. "Without him, I would not have dived into this field."

In a discipline where careers can be tainted just by association, that is a brave statement. But Gershenson is simply acknowledging the facts, he says. There was a very good reason why Schön was pursuing organic transistors, however dishonest his methods: they offer a radical and potentially lucrative new way to build cheap, light and flexible electronics. And that reason still stands.

The silicon transistors on today's circuit boards work by means of an electric field called a gate. When the gate field is on, it brings charges from within the silicon crystal up to the surface. When the density of charge on the surface is high enough, the crystal begins to conduct electricity there, so the circuit is on. Switch off the gate and the charges fall back into the crystal's interior, breaking the circuit.

It should work in organic crystals too. And if it does, it could lead to stronger, lighter and flexible plastic alternatives to rigid silicon chips. Several researchers at Bell Labs were testing the idea in organic crystals in the late 1990s, including Bertram Batlogg. In 2000 Schön, who was working for Batlogg, published

a paper describing the impressive properties of a new transistor made of a semiconducting crystal of pentacene. The crystal had a thin insulating coating of aluminium oxide to shield it from the gate electrode and prevent short-circuiting.

Gershenson remembers this paper being the talk of the condensed matter physics department at Rutgers. And as he was interested in the behaviour of charges in materials, he decided it was time for his lab to start work on organic electronics. He encouraged Podzorov to postpone the completion of his PhD – on an entirely different topic – and try his hand at making organic crystal transistors.

The same thing was happening in many physics departments around the world. Unlike some others, Podzorov's department had no background in organic electronics, so he started from scratch. He learned to grow organic crystals himself, instead of obtaining them from other people. And when, like everyone else, he could not get devices based on Schön's reported design to work, he combed earlier papers for clues. Eventually he found a description of transistor-like behaviour in an organic crystal from 1998. In that paper Schön used a crude method of insulating the crystal: he merely stuck a thick layer of a polymer called Kapton around it. Podzorov found this technique worked for him, too.

The aluminium oxide coating was notorious as the aspect of Schön's design that had proved most difficult to reproduce. Schön's method was to expose a disc of aluminium oxide, along with the organic crystal, to a cloud of plasma. The plasma vaporises the aluminium oxide and "sputters" it everywhere, including onto the crystal. Many researchers tried fine-tuning their sputtering machines in the hope of getting the experiment to work for them, but without success. It was Podzorov who worked out what the problem was.

One day late in 2001, he took a crystal that he knew worked fine when insulated with Kapton. "I put it in a plasma for a fraction of a second," he recalls. Then he tried the crystal in a circuit. "It was destroyed."

Podzorov concluded that an organic crystal that has been in a sputtering chamber cannot be used to make a transistor. "This is exactly the right scientific process, to do it one step at a time," says Horst Störmer, the Nobel prize-winning physicist who has spent many months trying to understand sputtering at Bell Labs.

So what to do instead? Podzorov remembered that, while working as an intern one summer at Honeywell Technologies in Morristown, New Jersey, he had seen circuits packaged in a thin clear layer of a polymer called parylene. The coating was applied simply by condensing parylene vapour onto the circuit. Podzorov tried it with another hydrocarbon crystal called rubrene and two months later ▶

**"Results were being published at the remarkable rate of once every 8 days. Then it all collapsed in scandal"**

# Crazy about crystals

Scandal nearly sank a revolutionary new chip without trace. Good thing some people know a great idea when they see one, says **Eugenie Samuel Reich**

A rogue physicist's work inspired Vitaly Podzorov (left) and Mike Gershenson