Sensing: THE ECONOMY OF SCALE IN SCOTLAND

Dr Shrawan Jha, Senior Engineer at CENSIS explains how the company is fostering microelectronics innovation in sensing technology for the Scottish economy

Sensor systems are big business. With an annual turnover of £2.6 billion in the Scottish economy and a worldwide market worth more than £500 billion, the industry is bursting with innovation. There's so much going on and Scotland is punching well above its weight.

In fact, the technology is a game-changer. It is a key enabler for achieving quality, efficiency and performance across all key markets – transport, defence, oil and gas, agriculture, the built environment, life sciences, and food and drink. The Centre for Sensor and Imaging Systems (CENSIS) is a newly-established innovation centre which aims to foster innovation in the sensors industry in Scotland.

CENSIS aims to grow the Scottish economy by supporting innovation in sensor development and their applications by initiating, facilitating and building collaborations among academic and industry partners across Scotland. It brings together businesses, entrepreneurs, funders and academics to develop new products, technologies, processes or services.

Among many examples, this working partnership has seen a Scottish company create smart collars for cows – producing real-time information for farmers on fertility and eating patterns. It has also allowed a food manufacturing company to use sensors to reduce wasted production downtime by making cleaning more effective.

Much of this has been achieved thanks to 'sensor element' which reflects a number of sensor technologies including, but not limited to, MEMS and nanotechnology.

Advances in nanotechnology have helped revolutionise multiple technologies, industries and products; often enabling novel solutions which were just not possible otherwise. Sensor technology is just one of those areas enormously benefited by nanotechnology.

However, nanotechnology is still evolving and continuously requires development of novel nanomaterials to fulfil its promise. In many cases, there appears to be a limitation on practical exploitation in electronics and, which affects the commercialisation potential of nano-electronic devices – even if they are feasible at lab scale. This is due to the random shape or distribution of nanomaterial, which causes large variation in device parameters even produced in the same batch.

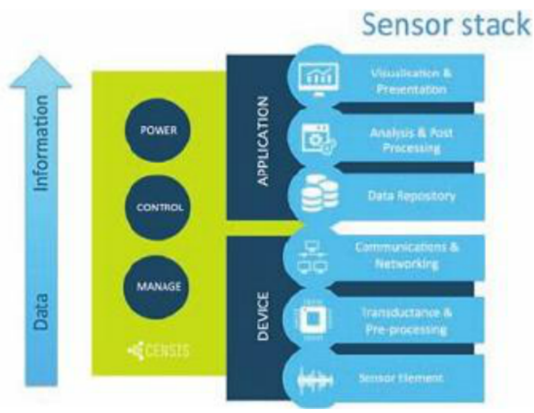


Figure 1: Schematic diagram of a six-level sensor stack

Figure 2: SEM image of a ZnO nanorod

To some extent, it is possible to control nanomaterial shape, dimensions, or areal distribution to acceptable levels. Nanomaterials can be classified in four major categories in terms of shape: 0-dimensional (nanoparticles, dots), 1-dimensional (nanowires, rods, fibres, whiskers, cables, tubes), 2-dimensional (thin Nano films) or 3-dimensional (complex shapes – colloids, flowers, tetrapods, spheres etc.).

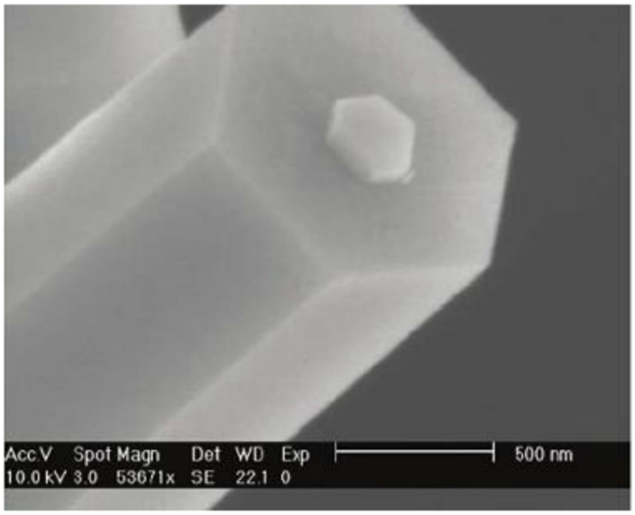
With a highly ordered growth, nanomaterials in dots or rods array can be integrated with baseline electronic materials and devices with reasonable reliability. For example, ZnO and GaN are two electronic materials which have material and electronic properties very close to each other. They both have a hexagonal lattice with a very small mismatch (1.8%) and a wide band-gap ~3.5-3.7eV and both are good materials for optoelectronic applications in deep blue to ultraviolet wavelengths range.

While GaN can be produced in n-type as well as p-type, ZnO can be produced reliably only in n-type. It is possible to form ZnO in many types of nanostructures and by multiple nano-synthesis methods with extremely good control; in contrast, forming GaN nanostructures with desired shape, size or distribution has been extremely challenging. Thus, these two materials have some compatible and some complementary features and so their integration enables novel solutions.

For example, solution processed n-ZnO NR gated AlGaN/GaN HFET based chemical sensors have been developed. Such devices promise high temperature application (such as gas sensing) over 200°C, and even room temperature operation without the need for heating elements in lab trials. Functionalising the nano-rods and passivation of the FET top surface can, in principle, allow selective sensing of multiple chemical elements in the centre's core team, with its members having long years of industrial or academic experience and technical expertise in each of the six levels in the sensor stack (Figure 1). The sensor 'stack' shows how elements can be integrated in sensor systems.

With the advent of high performance, low power processing and communication platforms, it is now possible to develop complex sensor systems that integrate many different sensor technologies into a sensor system.

The sensor-stack model can be applied to a simple sensor system such as a thermometer or weather van, or a highly complex network such as a battlefield management system or traffic management system. The first sensor stack is called



solution or gas forms, although it is yet to be proved in lab trials.

With sensor technologies becoming all-pervasive, the principal value is no longer just in the sensor and the data. It also lies in the system and the information it produces, as well as how this is managed, collected and presented back in a usable and useful format. Using that information effectively is the next challenge ahead and addressing this challenge will result in far more efficient and effective systems all around.

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