SENSITIVE PROCESSES BEHIND USING GaAs IN **POWER ELECTRONICS**

Image Karina Thånell, beamline manager at the I311 beamline, the beamline where Clifton performed their measurements.

Most electrical devices have to control and convert electrical energy, but a significant amount of energy is lost during these power electronics processes, reducing both power efficiency and reliability of electrical and mechanical systems such as hybrid and electric vehicles, solar inverters, wind turbines and home electronics. Experiments at the MAX IV Laboratory have provided methods for measuring the GaAs oxidation, which have helped the Estonian company Clifton AS to further develop their efficient Liquid Phase Epitaxy (LPE) technology.

There are currently three alternative semiconductor materials in use in power electronics – Silicon (Si), Silicon Carbide (SiC) and Gallium Nitride (GaN). Silicon does not perform well in higher energy density and temperature conditions, and SiC and GaN cannot be used for higher currents and are often too expensive.

GaAs has been widely used in microelectronics due to its suitability for high frequency and temperature, but not for controlling and converting electrical energy – not in power electronics as it has been complicated to find the technology to achieve higher reverse voltages.

LOWER ENERGY CONSUMPTION

The Estonian power electronics development company Clifton AS has developed Liquid Phase Epitaxy (LPE) technology, to produce efficient, fast, high voltage and low capacitance Gallium Arsenide (GaAs) structures and chips for power electronics. It opens the possibility for less energy consumption, smaller and lighter products.

The GaAs LPE production process is extremely sensitive and the properties of the material can rapidly change due to oxidation. Experiments at the MAX IV Laboratory enabled scientists to measure the GaAs oxidation in a way that has not been possible with other methods of measurement.

Clifton collaborates closely with the Institute of Physics at the University of Tartu and professor Ergo Nommiste, whose work includes participation in the development and evaluation of Clifton's proprietary LPE process. He was also entrusted with measuring potential oxidation during Clifton's production process.

"Clifton has to produce complex gallium arsenide structures", says Ergo Nommiste. "We knew that these can be easily affected by the air around them and that oxidation could cause the substance's properties to deteriorate, but the oxidation process was not measurable with our own equipment. The opportunity for beamtime at the MAX IV Laboratory via Science Link, was therefore very timely and it enabled us to conduct measurements at a completely new level."

OBSERVING THE OXIDATION PROCESS

On site at the MAX IV Laboratory, a series of experiments were carried out with different GaAs samples prepared by Clifton. These samples were differently exposed to ambient air. Unlike the experiments that were conducted in the home lab, these sensitive experiments showed oxidation process dynamics immediately after the sample was exposed.

"We could see exactly how oxidation progressed and how deep into the material it went", says Ergo Nommiste. "This means that Clifton has got proof of the dynamics of oxidation processes for different stages. The new knowledge enabled Clifton to further refine its processes."

Clifton's CEO Jaak Anton is very satisfied with the results. "Our close cooperation with the scientists of the Institute of Physics and the experiments at MAX IV Laboratory under Science Link enabled a deeper understanding of the processes and provided additional knowledge about the oxidation rates and compositions for different intermediate products. It gave us additional information to optimize our processes according to the results received by these measurements and we hope to make few additional measurements to verify decisions made", says Jaak Anton.

"The experiments at the MAX IV Laboratory provided critical information at a level which was impossible in our home laboratory. This enabled Clifton to further refine its sensitive processes".

Professor Ergo Nommiste, Institute of Physics, University of Tartu

Fact box

Clifton's measurements were carried out using the technique X-ray photoelectron spectroscopy (XPS) at the I311 beamline at the MAX IV Laboratory. XPS is a surface sensitive method that probes the chemical and electronic states that exists in a material. When a sample is exposed to X-rays it will eject electrons, which carry information about the sample's properties. In XPS one is typically interested in the behavior of core electrons, i.e. electrons in the inner shells of atoms. By analyzing the kinetic energy of the electrons ejected from the core of a specific element it is possible to deduce the chemical and electronic state of atoms of that particular element. Clifton studied core electrons in Ga and As in order to learn about the oxidation dynamics of GaAs semiconductor surfaces.

Science Link is a network between leading research facilities of photon and neutron sources and its users. The project aims to support and encourage innovation and entrepreneurship in the Baltic Sea Region. Apart from the research facilities, the network also includes scientific institutes, universities and regional organisations that serve as service and promoting units. Science Link is part-financed by the European Union (Baltic Sea Region Programme) and involves 17 partners from 8 countries during the project period 2012 to 2014.

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