

Projektledare Olof Kordina
Projekttitel Utveckling av isotropen kiselkarbid och galliumnitrid för energitillämpningar

Administrativ bilaga till Slutrapport

1. Projektets måluppfyllelse

a) The project goals are:

- SiC epitaxial growth in a hot-wall CVD reactor using a completely new growth concept.
- Investigate isotope enriched 4H-SiC and specifically measure the κ in both directions and compare it to natural 4H-SiC. Investigate if we can detect an increase in the electrical conductivity.
- Investigate the influence of structural defects, like dislocations and stacking faults, on the thermal conductivity.
- Produce SiC n- epi of 4H $^{30}\text{Si}^{13}\text{C}$ for possible high power applications.
- Perform fundamental studies on isotope enriched SiC and effects of polytype.
- Explore isotope enriched GaN.

We have successfully developed growth of high-quality epitaxial isotope enriched 4H $^{28}\text{Si}^{12}\text{C}$. We have shown that the thermal conductivity of isotope pure 4H $^{28}\text{Si}^{12}\text{C}$ is 20% higher compared to its natural counterpart. Even a higher increase of thermal conductivity by 34%-36% was demonstrated for isotope enriched 3C $^{28}\text{Si}^{12}\text{C}$.

A high thermal conductivity will improve the performance of a device in several ways:

- The high thermal conductivity will reduce the temperature at the junction which improves the mobility and hence reduces the resistance at the operating temperature.
- The improved thermal conductivity can also allow a higher current density which reduces the size of the device which reduces the capacitance and hence reduces the switching losses.

In a follow up project (Osiris) we shown that a significant temperature reduction of around 10% could be measured on GaN HEMTs on the isotope enriched SiC substrates.

2. Kommentera eventuella betydande avvikelser i projektets måluppfyllelse och/eller genomförande i förhållande till Energimyndighetens beslut om stöd till projektet

The research within the project have been done in line with the proposed plan and the goals for SiC have been achieved to a large extent. We could not explore $4H^{30}Si^{13}C$ due to difficulties in transforming the isotope rich Si source in SiH_4 needed for the growth (2 MSEK was needed for the production of the tool without a possibility to own it). The last goal to explore isotope enriched GaN was not achieved due to sudden increase in the cost of isotope enriched Ga source which render impossible to purchase it. Note that the cost was substantially exceeding the available budget and initial quote. These deviations are not considered significant as the main goals of the project have been achieved. The research developed in this project served as a basis for two EU projects by LiU and SweGaN (spin-off of LiU) in the area of 5G where we contributed with developments of GaN HEMT technology on isotope-enriched SiC.

3. Spridning och nyttiggörande av resultatet i samhället

a) The results from the research within the project have been reported at several scientific conferences and in a number of journal publications (see detailed publications in report). Additionally, papers that summarize findings from the project are in preparation and will be reported to the Swedish Energy Agency after publishing.

b) The following two patents were filed:

1. Isotope enriched silicon carbide with enhanced thermal conductivity for energy applications. PCT/SE2014/050807. This patent describes a way to produce isotope enriched SiC. The isotope enriched substrates have a higher thermal conductivity and would hence help dissipate heat and make devices more efficient.

2. Inexpensive semi insulating substrates, Swedish application 1430022-2. PCT/SE2014/050807. This patent describes how to produce less expensive semi-insulating substrates. These substrates are very expensive to purchase today and is our greatest cost. The patent also describes making these substrates isotope enriched. The patent authority felt that this was two inventions and recommended that this patent is split into two. I am checking the latest information about this.

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4. Eventuella bilagor till rapporten som inte ska visas i Energimyndighetens externa projektdatabas

<input type="checkbox"/> Ja <input checked="" type="checkbox"/> Nej