PiezotronicNanoProbe

Piezo-phototronic effects in 3rd generation semiconductors by extreme pressure application with nanometer resolution

Programm / Ausschreibung	DST 24/26, DST 24/26, Bilateral Call with the Chinese Academy of Sciences, 2024	**Status**	laufend
Projektstart	01.11.2024	**Projektende**	31.10.2026
Zeitraum	2024 - 2026	**Projektlaufzeit**	24 Monate
Keywords	nanomechanical force applicator, piezo-phototronics, 3rd generation semiconductor		

Projektbeschreibung

Halbleiter der dritten Generation wie ZnO, GaN und SiC weisen im Vergleich zu den Vorgängergenerationen bessere physikalische Eigenschaften wie eine größere Bandlücke, eine höhere Sättigungsgeschwindigkeit, eine höhere Wärmeleitfähigkeit und einen höheren Schmelzpunkt auf. Aufgrund ihrer hexagonalen Wurtzit-Kristallstruktur unterliegen sie dem piezoelektrischen Effekt und weisen daher ein piezoelektrisches Potenzial (Piezopotenzial) auf, wenn sie einer mechanischen Belastung ausgesetzt werden. Das Hauptziel dieses Projekts ist es experimentell zu untersuchen wie ein stark lokalisierte extreme mechanischer Druckbelastung (bis zu 10 GPa) die elektrischen und optischen Eigenschaften von piezophotronischen Bauelementen beeinflusst. In dem vorgeschlagenen Projekt "PiezotronicNanoProbe" werden Piezophotronik-Experten des CAS-BINN mit Experten für Rasterkraftmikroskopie (AFM) und Mikroantilever aus Österreich zusammenarbeiten, um einen sogenannten "Nanomechanical Force Applicator" (NFA) zu entwickeln. Dieses einzigartige System wird es erstmals ermöglichen bahnbrechende Experimente zu piezo-photronischen Effekten in GaN-basierten Laserdioden durchzuführen.

Abstract

Third generation semiconductors such as ZnO, GaN, and SiC exhibit superior physical properties such as a higher band gap, a higher saturation velocity, an increased thermal conductivity, and a high melting point compared to the previous generations. That’s why they are often referred to as “the future trend” in semiconductor technology. However, there is another extremely important characteristic of third generation semiconductors that has the potential to be the enabling key technology for numerous future applications: Due to their hexagonal wurtzite structure, they are subjected to the piezoelectric effect and thus exhibit a piezoelectric potential (piezopotential) when exposed to mechanical strain. As they show both, piezoelectric and semiconductor properties, the piezopotential created in the crystal has a strong effect on the carrier transport process. This fundamental principle of piezotronics was introduced in 2007 by Prof. Zhong Lin Wang, who is the director of CAS-BINN. In 2010, Prof. Wang, proposed the principle of the piezo-phototronic effect, which is a three-way coupling effect of piezoelectric, semiconductor, and optical properties. Despite numerous researchers working in this field, many fundamental effects in piezotronics and piezo-phototronics are still barely investigated. An important research question in this context is: “How does a highly localized extreme mechanical stress influence the electrical and optical

properties of piezo-phototronic devices?" Although several simulation-based predictions have been published, experimental validations are still missing. In the proposed project, piezo-phototronic experts of CAS-BINN will team up with atomic force microscopy (AFM) and microcantilever experts from Austria to develop a Nanomechanical Force Applicator (NFA) to enable such experiments for the first time. The NFA design exploits basic elements of an AFM, but has additional unique functionalities: First, the cantilever serves as an extreme pressure applicator and not as a topography probe. Second, the bending of the cantilever tip is electrically measured via piezoresistive strain gauges on the cantilever. This eliminates the laser readout used in traditional AFMs, which would spuriously interfere with the piezo-phototronic device under investigation. The cantilever itself will be made of a custom-made multilayer stack to achieve the cantilever key parameters (spring constant, resonance frequency, Q-factor, bending, force sensitivity). Third, the tip must be custom-shaped to achieve a well-defined contact surface for precise pressure calculation from the applied force. Shaping is very challenging as the tip material must be very hard to withstand extreme compressive loads. The project partners will use this NFA system to perform groundbreaking experiments on GaN laser diodes. For example, the emission characteristics of the laser diode as a function of the applied pressure to the ridge of the diode will be investigated. CAS-BINN will also study the laser diode emission characteristic as a function of the location where the pressure is applied to the sample. Transient effects like light output modulation by pressure variation will also be analyzed. In conclusion, the NFA system will provide CAS-BINN a worldwide unique tool to perform experiments on piezo-phototronic devices that would otherwise not be possible. This will give CAS-BINN a decisive advantage in this highly competitive research field.

Projektkoordinator

- Universität für Weiterbildung Krems

Projektpartner

- c-sense GmbH