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50. Internationales Wissenschaftliches Kolloquium
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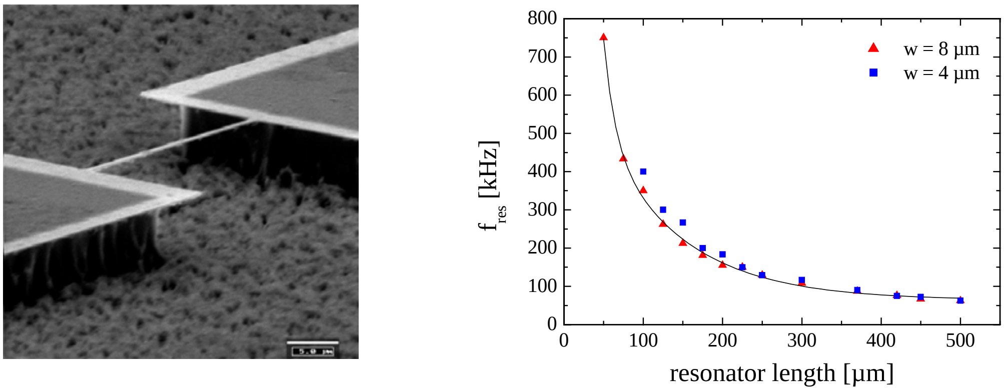
Group III-nitrides and 3C-SiC for micro- and nanoelectromechanical resonators

During the last years strong activities have been performed in the field of microelectromechanical systems (MEMS) and to scale them down to the sub micron range. MEMS consist on a combination of micromechanical structures with electrical active elements for the actuation and read-out of the sensor signals. Applications for these devices can be found in many fields including high frequency communication as well as sensing of biomolecules. Decreasing the dimensions of the mechanical elements down to the sub-micron scale bears the new category of nanoelectromechanical systems (NEMS). The research on NEMS is focussed on nanoresonators in order to achieve very high frequencies devices for electronic filters operating in the GHz range. This opens the door to new applications like low power high frequency devices for portable communication as well as high sensetive sensors for the detection of single molecules in combination with functionalised surfaces. Our focus is the application for measuring the viscosity of small quantities of water-based liquids and to determine the weight of proteins which placed on the resonator surface.

Resonators down to the sub micron range have been demonstrated already based on silicon or SiC. However, scaling down geometries requires increasing efforts in the design and the NEMS technology. In particular, to keep the complexity of the NEMS and the manufacture technology on a reasonable level, the actuation and the read out need further development of new principles and designs. The goal is to achieve integration to the resonator itself, which requires a special attention on the selected material system with respect to the desired functions. In the ideal case just one material or material system should be used to realise the resonator, the actuator and the read out. The group III-nitrides represent such a system. The wurtzite structure of wide bandgap semiconductors like AlN combine piezoelectric effects with advanced electronic and optical properties. The high chemical and mechanical resistance of SiC and the group III-nitrides make these materials especially for MEMS and NEMS suitable. First, the piezoelectricity of AlN and AlGaN allows an easy integration of actuators for the nanoresonators. Second, polarization induced sheet charges and two dimensional electron gases (2DEGs) at heterointerfaces of AlGaN/GaN heterostructures are highly sensitive on mechanical deformation og the crystall and can be used for pressure sensors as well as for the detection of the oscillating resonator. Finally, for group III-nitride based heterostructures deposited on silicon substrates the combination with the highly developed processing technology for silicon micromachining allows the fabrication of resonator structures using established lithography and etching techniques.

For the different resonators epitaxial 3C-SiC layers were grown by chemical vapor deposition, binary AlN and AlGaN alloys as well as heterostructures were deposited by plasma induced molecular beam epitaxy and sputterdeposition on Si substrates. Conventional optical lithography was used to define bridge like resonator structures with dimensions of 0.5 – 8 µm and 2 - 500 µm in width and length, respectively. The thickness of the bars was reduced to a minimum 100 nm. In Fig. 1 realised resonators and measured resonance frequencies are shown.

a)



b)

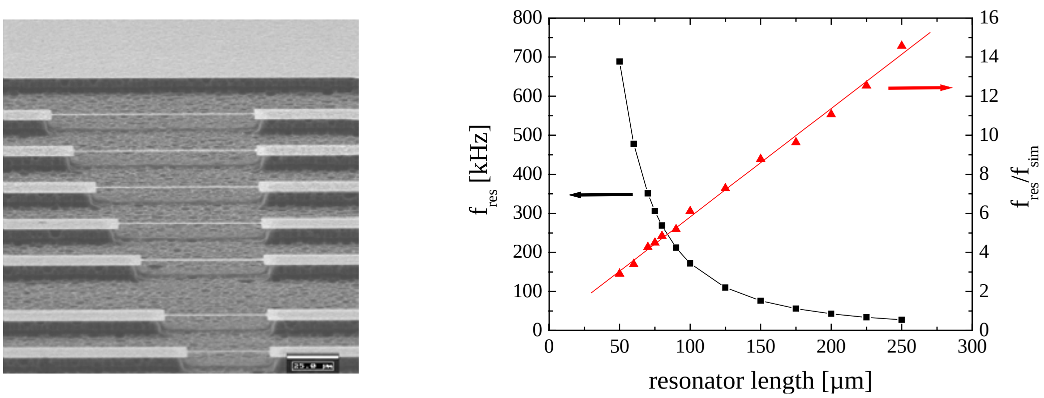


Fig. 1: a) AlN based nanoresonator and resonance frequencies of beams with different width, b) array of 3C-SiC resonator beams with resonance frequencies and ratio between measured and simulated resonance frequencies.

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