

The Invisible Hand: Building High-Frequency Acoustic Tweezers for Microparticle Manipulation

Fabrication of Silicon-Based 300 MHz Ultrasonic Transducers in the Cleanroom

Type of Thesis: Diploma, master, bachelor, student thesis

Suitable for: Material Science, Nano Technologies

Motivation & Background:

Ultrasound is widely established in diagnostic medical imaging and non-destructive material testing. Beyond imaging, acoustic waves can also be used for localized heating and—more intriguingly—for the contactless manipulation of matter. Using acoustic radiation forces, particles can be moved, guided, trapped, or levitated.

Such **acoustic tweezers** have been demonstrated at kilohertz frequencies in air, enabling the levitation of biological tissue and even small living organisms. This contact-free manipulation acts like an “invisible hand” and is particularly attractive for handling fragile, heterogeneous, or contamination-sensitive samples.

To manipulate significantly smaller objects—such as individual cells in liquid environments—the acoustic wavelength must be reduced accordingly. This requires a substantial increase in operating frequency into the hundreds of megahertz range.

In 2017, a research group at the University of Southern California demonstrated the manipulation of 5 μm polystyrene particles using a **300 MHz silicon-based transducer**. Their work shows that high-frequency ultrasonic devices enable precise particle control in water and open the possibility of manipulating individual biological cells rather than larger tissue samples in air.

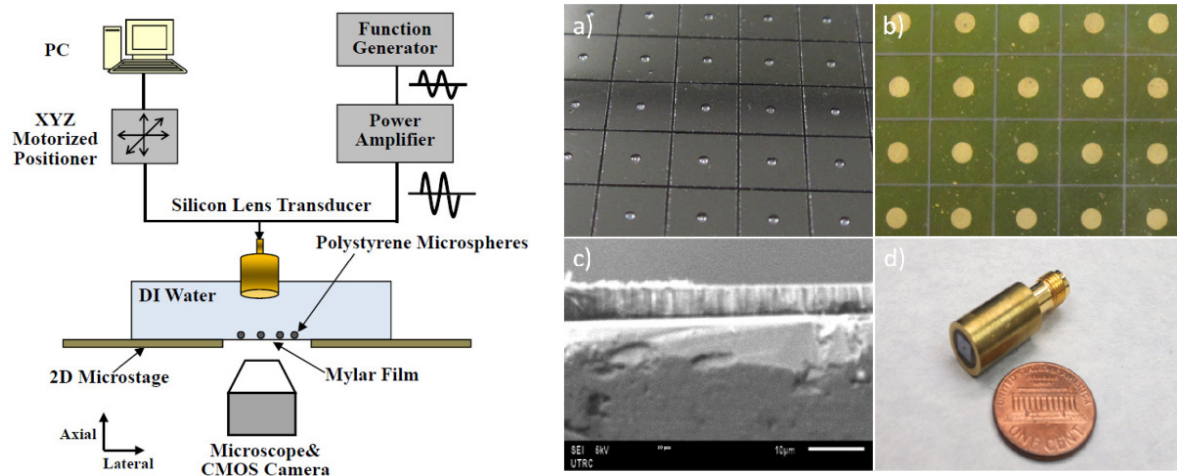


Figure 1: Concept of particle manipulation using ultrasound (left) and silicon-based ultrasound devices (taken from <https://doi.org/10.1016/j.jallcom.2017.09.113>)

In collaboration with **PVA TePla Analytical Systems GmbH (Westhausen, Germany)**, we aim to rebuild and further develop such silicon-based high-frequency transducers in the Cleanroom facilities of TUBAF.

Goals & Objectives:

The primary goal of this thesis is to experimentally reproduce the key findings of the referenced publication and to establish a reproducible fabrication process for silicon-based acoustic lenses operating in the ~300 MHz regime.

To achieve this, the following objectives must be addressed:

- Investigation and evaluation of suitable silicon micromachining (edging) processes to fabricate spherical acoustic lens geometries
- Determination of process parameters to achieve defined lens diameters and depths
- Design and fabrication of lithographic masks (if required)
- Geometrical and surface characterization of fabricated silicon lenses
- Preparation of optimized silicon substrates for subsequent ZnO sputtering at PVA TePla

The long-term objective is to enable the fabrication of functional high-frequency ultrasonic transducers for acoustic particle manipulation in liquids.

Milestones:

M1: Literature review and comparison of silicon micromachining/edging processes; selection of suitable fabrication approach and parameter window.

M2: Design of the experimental process flow and cleanroom implementation strategy at TUBAF.

M3: Fabrication of first test wafers with spherical lens structures.

M4: Geometrical characterization of lens profiles (radius, depth, surface quality) and evaluation of reproducibility.

M5: Process optimization based on characterization results; refinement of fabrication parameters.

M6: Fabrication of multiple optimized silicon lenses ready for ZnO sputtering at PVA TePla to form functional transducers.

M7: Characterization of the acoustic sound field of the completed transducers and comparison with literature results.

Character of the work:

20 % literature and concept development, 60 % experimental cleanroom fabrication and process optimization, 20 % characterization and data evaluation.

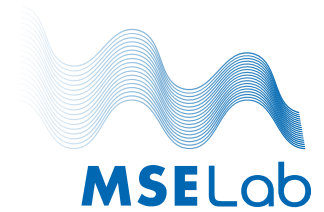
Supervision & Workflow:

- Meetings: weekly meetings between student and supervisor to evaluate status and progress and identify need for support; time and location (also possibly online) will be determined at the beginning of the work; additional meetings for any necessity are highly encouraged
- Lab works: The project pursues several works in the lab, which requires a reliable and structured workflow. Furthermore, the student will get a safety briefing for the house and the lab and the clean room.
- Weekly reports: The student is required to write a weekly report at the end of each week and to send it to his advisors or document it in git. The idea of the weekly report is to briefly summarize the work, progress, and any findings made during the week, to plan the actions for the next week, and to bring up open questions and points. The weekly report is also an important means for the student to get a goal-oriented attitude to work.
- Mid-term presentation: Students are encouraged to give a mid-term presentation as a preparation for the final presentation of the thesis. This is an opportunity to discuss the results with a broader audience and get important feedback on the current state of the work.



TUBAF

Die Ressourcenuniversität.
Seit 1765.



Technical Details:

- A commercial SAM is available, which can be used to test transducers
- The Students should be familiar with the Clean-Room of TUBAF
- The design and manufacturing of lithographic masks is part of the thesis work.

Supervisor: Dipl.-Ing. Emanuel Leipner