ShanghaiTech University

Nurturing future talent and collaboration is key to success

ShanghaiTech University is a young, resource-rich university with a modern residential campus in the heart of Shanghai Pudong's Zhangjiang Hi-Tech Park. With an academic focus on STEM research, the university is committed to carrying out top-notch research and nurturing the next generation of innovative scientists, inventors and entrepreneurs. The university seeks cutting-edge solutions to address the challenges that China and the world are facing in the fields of energy, material, environment, human health, and artificial intelligence.

Professor Wu

In an interview with LAYERS **Professor Wu** explains more about the work at PMICC, the importance of collaboration, and how thin film technology capability provided by companies like Evatec is helping his own group and others develop world leading piezo thin films and devices.

Please tell us about work of your department and the field of your research.

The PMICC center aims to promote the research and applications of novel devices, circuits, and systems. Our mission is to realize high energy-efficient computing for emerging applications from the perspectives of fundamental research core techniques in physical principles, devices, circuits, and systems. The center is exploring technologies ranging from cryogenic electronics, spintronics, optoelectronics, Micro-ElectroMechanical Systems (MEMS), III-V compound semiconductors, electronic design automation, system-on-chip, signal processing, reconfigurable computing, digital circuit design, and custom computing for robotics, smart vehicles, and so on.

At this time we have 18 principal investigators and more than 100 graduate students.. We are also actively participating in several national/CAS key R&D research programs with more than 50,000,000 RMB funding. In addition, under the framework of several research platforms including ShanghaiTech Microelectronics Research Center, ShanghaiTech-UC Berkeley BDMC, and ShanghaiTech Quantum Device Nanofabrication Laboratory (SQDL), we also collaborate with IC companies and universities to push emerging IC research forward.

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上海科技大学 ShanghaiTech University

PMICC 后摩尔器件与集成系统中心 Post-Moore Microelectronics Integrated Circuit Center

What kind of process and test equipment do you have available?

We are able to offer multiple deposition technologies including sputter, e-beam evaporation, thermal evaporation, PECVD, ALD, LPCVD, etc. plus etch, lithography and a whole range of test equipment measuring film surface profile, thickness,, stress, piezo properties etc. We have a complete 4/6 inch line and can also make development on anything between 2 and 8 inch.

How do you support the wider academic / industrial community?

We see networking and wide collaboration as key to success. We are located adjacent to some of the leading scientific and research institutions in China. The area also hosts headquarters and R&D centers for many high-tech corporations such as Baidu, Huawei, Tencent, SMIC as well as multi-nationals including Qualcomm, IBM, Pfizer, and Astra-Zeneca.

A number of our faculty graduated from or worked at leading institutions, including MIT, Berkeley, Caltech, UIUC, UCLA, EPFL and others before joining us. We strongly believe that it is through international perspectives as well as value for both innovation and fundamental research that our faculty can impart the highest standards of knowledge and guidance to our students. So an important part of our work is help other groups by providing access to our equipment and know-how.

How does equipment from Evatec help you in your research?

Our CLUSTERLINE® 200 PVD system provides us with a world-class system and capability for Mo/AlN/AlScN thin film deposition.

We have collaborated with Evatec to achieve high quality AlN/AlScN deposition on Si, SiO_2, sapphire, SiC substrates. We have also been able to address the emerging interest in high Sc content AlScN films, especially ratios over 30%, through process development, film quality characterization, piezoelectric acoustic transducer design and testing.

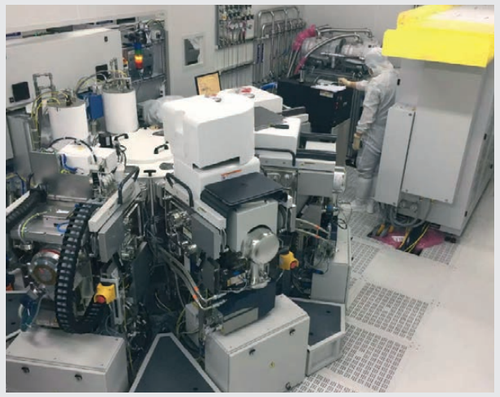
We have already provided sample materials through collaboration with more than 30 universities, institutes or companies in China, Singapore and United States etc.

What do you see for the future?

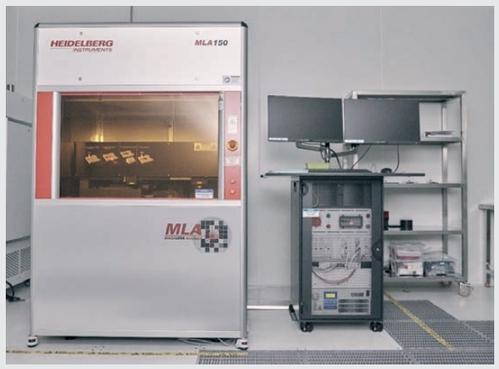
The future is all about collaboration - at Shanghaitech Microsystem And noveL transducers Laboratory (SMALL) we are developing chip-scale sensor and actuator systems with novel material and micro/nano-fabrication processes. Specific research areas of interest include Micro-/Nano-Electro-Mechanical System (MEMS/NEMS) design and modeling, novel multiferroic materials, processing and acoustic transducers, MEMS-CMOS IC design as well as their applications in smart hardware, next-generation communication, Internet-Of-Things (IOT) etc. We welcome collaboration with all scientific and engineering groups joining together to explore fascinating micro/nano-technologies. So please do get in touch!

Nanofabrication Cleanroom

Elionix ELS F125 Ebeam Lithography System



Evatec CLUSTERLINE® 200 Sputtering System



Heidelberg Mask Less Aligner MLA150

About the work of PMICC

In the past five years, we have published 200+ highly-impact journal papers and 110+ top conference papers, including Science, Science Advances, Nature Materials, Nature Nanotechnology, Nature Communications, Proceedings of the IEEE, Nano Letters, ACS Nano, Optica, ACS Photonics, Electron Device Letters, Applied Physics Letter, JMEMS, Micromachines, IEEE MEMS, TRANSDUCERS, DAC

Some recent highglights

1. Journal of Michromechanical Systems
High Quality Co-Sputtering AlScN Thin Films for Piezoelectric Lamb-Wave Resonators
In this article, we have demonstrated optimized AlScN co-sputtering and etching processes in close collaboration with Evatec. High scandium concentrations of the AlScN thin films require more plasma energy during grain growth, which can be achieved by reducing N2 gas flow rate to increase the energy obtained from plasma. However, the N2 flow rate in turn affects the stress. The balance between crystalline quality and stress needs to be considered when selecting the flow rate. In addition, inappropriate energy could lead to Sc accumulation with an increase in the number of abnormal orientation grains. The XRD FWHM of AlScN can be used directly to evaluate the piezoelectric constants. By optimizing the deposition condition, 500 nm Al0.85Sc0.15N thin films with a FWHM of 1.75°, an average stress of –27.5 MPa and a stress range of 107 MPa over 4-inch area are obtained. The dry etching rate of AlScN could be significantly improved by increasing the RF power. An etching rate of 130 nm/min and a profile of over 77° are achieved. Finally, Lamb-wave resonators have been fabricated based on Al0.78Sc0.22N a n d A l0.85Sc0.15N thin films, achieving a quality factor of over 1000, as well as 152% and 80% improvement in electromechanical coupling coefficients, compared to pure AlN thin film devices, respectively. The significant increase in electromechanical coupling coefficients brought by high quality and high Sc-doped AlScN demonstrates the great potential in RF applications.

https://doi.org/10.1109/JMEMS.2022.3161055

2. Jourmnal of Electron Device Letters
Low Loss Al0.7Sc0.3N Thin Film Acoustic Delay Lines
In this work, we have successfully demonstrated the first unidirectional Al0.7Sc0.3N thin film SPUDT ADLs. The fabricated Al0.7Sc0.3N ADL achieves a low IL of 2.27 dB and an FBW of 7.1% at center frequency of 780 MHz. The extracted group velocity of Al0.7Sc0.3N is 8505 m/s. The coupling coefficient boosted by Sc doping enhances the overall performance comparing to the AlN counterparts. Upon further development, AlScN could enable CMOS process compatible piezoelectric acoustic platforms for chip-scale integrated signal processing, sensing, and computing applications.

https://doi.org/10.1109/LED.2022.3152908

3. Journal of Applied Physics Letters
Al0.7Sc0.3N butterfly-shaped laterally vibrating resonator with a figure-of-merit (kt2·Qm) over 146
Our works take advantage of both the fabrication process and device design. Fabrication challenges are addressed with the Al0.7Sc0.3N thin film, especially for piezoelectric thin film sputtering and dry etching. The realized LVRs with butterfly-shaped boundaries agree with the predicted improvement in performance. Compared with the LVRs with flat boundaries, the same LVRs with butterfly-shaped boundaries achieve 40% progress in FoM. Also, a tuning range of 1.8 MHz is achieved for a 304.8 MHz Al0.7Sc0.3N LVR by applying DC voltage in the range of -40 to 40 V. The fabricated LVRs have low-impedance Rm of 7.09 Ω, which is suitable for RF filters. The operating frequency of LVRs can be scaled up to GHz range with advanced lithography tools and high-order lamb wave modes. With the high FoM of 146.2 and high phase velocity of ~7320 m/s, the reported Al0.7Sc0.3N LVRs are promising candidates for use in RF communications in the future.

Link: https://doi.org/10.1063/5.0090226

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