MEMS and NEMS
Room Central Hall - Session MN-ThP
MEMS and NEMS Poster Session

MN-ThP-1 Fundamental-mode Surface Acoustic Wave Magnetoacoustic Nonreciprocal Low-loss RF Isolator for Efficient Control of NV− Centers*, **Bin Luo**,* Northeastern University, US*; A. WINKLER, H. SCHMIDT,* SAWLab Saxony, Germany*; B. DAVAJI, N. Sun,* Northeastern University, US

Owing to long coherence time, high fidelity and easy optical initiation and readout of quantum states tuned by magnetic excitations over a broad temperature range, NV^{-} centers are intriguing solid-state platforms for quantum computing, communication, information processing and sensitive non-invasive nanoscale magnetic sensors [1-5]. Traditional control of NV^{-} centers were realized by microwave striplines or antennas, which consume high power on the order of 1~10 W but yields low magnetic field even at a short distance of 1 mm [6-8]. The surface acoustic wave (SAW) delay line driven spin wave enabled by magnon-phonon interactions exhibits superior properties of high-power efficiency, low noise and small footprint, leading to efficient voltage control of NV^{-} center. Recent demonstration of NV^{-} center excited states control by 5th-order-SAW-driven spin wave in a 20 nm Ni film shows comparable Rabi frequencies with 1300 times less power than microwave excitation [9]. However, the low magnitude of high-order SAW and the high damping of Ni film degrades the efficiency and coherence time of NV^{-} center control and hinders the realization of efficient control of NV^{-} center ground states exhibiting longer lifetime.

Recently, magnetoacoustic non-reciprocal RF devices exhibit substantial nonreciprocity with remarkable power efficiency and CMOS compatibility, making them ideally suited for low-power and one-directional quantum transducer. Non-reciprocal magnetoacoustic devices consist of a magnetic stack situated between two interdigital transducers (IDTs) on a piezoelectric substrate. By applying RF voltage on IDTs, the induced SAW propagates and interacts with SW in the magnetic stack. The strong magnon-phonon coupling leads to hybrid magnetoacoustic waves that exhibit a much higher backward loss rate than the forward one or vice versa. Ongoing research strives to enhance non-reciprocity strength and bandwidth while maintaining high transmission between device ports [10]. Despite successful demonstrations of magnitude or phase non-reciprocity in various magnetic stacks such as antiferromagnetically coupled FeGaB/Al_2O_3/FeGaB stack [11-12], the insertion loss is still high (>50 dB) owing to the low transmission of SAW high-order mode. Here we demonstrated a low-loss magnetoacoustic non-reciprocal device driven by SAW fundamental mode at 2.87 GHz. The 10-dB low insertion loss and strong non-reciprocity of 23.5 dB/mm make the device potential for coherent and efficient control of NV^{-} center ground states and the realization of non-reciprocal quantum transducer for one-directional quantum information transfer.

MN-ThP-2 3D Carbon Nanotube Collimators Grown on a Transparent Substrate for Diffuse Spectroscopy*, **Bridget Kemper**, W. Parker,* Brigham Young University*; T. Westover,* Tula Health*; R. Vanfleet, R. Davis,* Brigham Young University

Miniaturized spectrometers could enable the application of spectroscopy in wearable devices such as fitness/health monitors. In prior work, miniaturized spectrometers with carbon nanotube parallel-hole collimators were fabricated for use in diffuse light spectroscopy. The miniaturized collimators were formed using carbon nanotube templated microfabrication (CNT-M). CNT-M collimators were grown on an opaque silicon substrate and removed for use. For the CNT-M structure to be robust enough for transfer, it requires significant carbon infiltration. However, this infiltration step results in increased sidewall reflection, impairing the collimation of light. Here we present the use of a transparent fused silica growth substrate. This allows the collimators to remain on the transparent substrate in spectroscopy applications, circumventing the need for infiltration and substrate removal steps. Omitting the carbon infiltration reduced sidewall reflection and improved collimation performance.

MN-ThP-3 Pressure Controlled Brazing to Form Microscale Metal Fluidic Interfaces*, **David Hayes**, J. Grow, H. Davis, B. Jensen, N. Crane, R. Vanfleet, R. Davis,* Brigham Young University

2D and 3D metal microchannels have been fabricated using diffusion bonding and metal additive manufacturing for applications including micro heat exchangers and microcolumns for gas chromatography. However, creating precise and robust fluidic interfaces remains challenging for these microchannel applications. Brazing is a potential method for forming microscale fluidic interfaces but introduces the risk of clogging the fluidic channel with the molten filler metal. Here, we present brazing methods for interfacing stainless steel capillary to microfluidic parts. We used a powder-based method of pressure control which allowed the filler metal to form a precise hermetic seal at the fluidic interface without clogging the channel. We demonstrate this method by hermetically interfacing two 100 µm inner diameter stainless steel capillaries without clogging. Along with pressure and flow testing results, scanning electron cross-sections (see example in the supplemental figure) show the morphology of the brazed interface.

MN-ThP-4 Concurrent Mitigation of Packaging Stress and Support Loss in Microacoustic Resonators*, **Maliha Sultana**, T. Hasan, J. Vivas Gomez, K. Chan, H. Mansoorzare, R. Abdolvand,* University of Central Florida

In this work, the effectiveness of compact isolation frames in mitigating the stress-induced frequency shifts and concurrently boosting the quality factor (Q) of piezoelectric MEMS resonators is studied. Piezoelectric MEMS resonators are a promising candidate for replacing quartz and capacitive resonators. However, having multiple anchor points makes them susceptible to failure due to packaging induced stress. Here, by introducing tailored trenches around said resonators and experimentally comparing their performance with baseline devices, it is shown that the stress-induced frequency shifts are reduced by up to ~94%. Moreover, compared to baseline, the isolation frame boosts the Q of the devices by up to 2.9x, while minimally impacting the device footprint.

Commercially available capacitive MEMS resonators have weak electromechanical coupling which results in higher loss and limits their application in low power scenarios. To overcome this issue, a viable solution is piezoelectrically exciting/detecting the vibration of a single crystal MEMS resonator, as shown in thin-film piezoelectric-on-silicon platform with promising results. However, commercializing this platform is challenging due to packaging and unwanted stresses (e.g., from die attachment material) that translate into the resonant body, causing frequency drifts. This is exacerbated by having two or more anchoring points to substrate that suspend the resonant body. To mitigate this impact, auxiliary trenches with specific geometry are designed (using COMSOL) adjacent to the resonant body to ensure compact footprint. Thickness-lamé mode resonators with low thermoelastic damping are designed and fabricated using a stack of 1um AlN on 21um Si with a frequency around 145MHz.

To evaluate, the resonator die is affixed to a PCB using an epoxy die attachment suspended over another PCB and supported with screws. Stress is applied by tightening screws to bend upper PCB while frequency response of the resonator is recorded by micro-probes connected to network analyzer. Experimental results show, the bending can cause a maximum frequency shift of 18KHz in baseline, which is reduced to around 1KHz (18x reduction) in a device with isolation frame. The curvature of the devices measured using Keyence 3-D Optical Profiler follows the same trend; devices with isolation frame show less bending which implies less impact from stress. Finally, the effectiveness of the isolation frame in reducing the anchor loss is evident by the higher measured Qs compared to baseline. Detailed experimental setup and results demonstrating the effectiveness of isolation frame is available in the provided supplementary document.

Author Index

Bold page numbers indicate presenter