**Docket #:** S13-424

# Tunable, Integrated Magnetoelectric Components for Wireless RF Communications

Engineers in Prof. Shan Wang's laboratory have developed a CMOS-compatible fabrication method to integrate compact, tunable magnetic components into mainstream semiconductor electronic devices. Specifically, the thin-film devices have multi-axial, radial, or non-uniform magnetic anisotropy enabled by electrical control of magnetization. Previously, anisotropy was restricted to one axis, which limited the performance of devices with thin-film magnetic cores. This technology improves the efficiency of those devices by employing a composite heterostructure comprised of hard piezoelectric and soft magnetic layers. With this design, an applied voltage across the piezoelectric layer will reorient the magnetic layer to induce local magnetic anisotropy in a desired direction, maximizing efficiency of high-frequency magnetic devices. This technology could be used to integrate magnetoelectronics into a variety tunable wireless radio frequency (RF) electronics for a wide range of near field communications.

**Stage of Research**
The inventors built a fully-integrated semiconductor device prototype with compact magnetoelectric modulators for tunable RF wireless communications. They were able to to reversibly tune the resonance frequency by controlling magnetic permeability, with a converse magnetoelectric coupling coefficient of up to 24mG cm $V^{-1}$, demonstrated across several wireless channels using as little as ~6V µm electrical field.

## Applications

- **Magnetoelectric devices for RF electronics and wireless communication**

    - high-frequency magnetic devices, such as toroidal or coupled:
        - integrated inductors for radio transmitter/receivers
        - transformers
        - resonators
    - end-user applications such as near field communications for Internet-of-Things devices

## Advantages

- **Broadly tunable devices across multiple channels:**
    - tune by altering inductance post-fabrication using electric current to adjust anisotropy
    - tune to hop across communication channels that are typically 20 MHz wide in frequency with as little as ~6V µm electrical field
- **Efficient high-frequency components** - multi-axial anisotropy enables flux to efficiently couple through entire core of the devices
- **CMOS-compatible thin-film fabrication** for integration in semiconductor devices

## Publications

- El-Ghazaly, A., Evans, J. T., Sato, N., Montross, N., Ohldag, H., White, R. M., & Wang, S. X. (2017). " Electrically Tunable Integrated Thin-Film Magnetoelectric Resonators." *Advanced Materials Technologies.*

## Patents

- Published Application: 20150206657
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## Innovators

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