A Wearable Strain Sensor Captures *In Vivo* Tumor Progression

By Weilai Yu

In cancer therapeutics, extensive drug screening is a critical but labor-intensive process of testing thousands of potential drugs to pick the most effective one against a certain cancer type. Oncology researchers employ a suite of *in vitro* models that assess the efficacy of numerous drugs quickly and inexpensively. However, *in vivo* tests deliver results that are more closely related to clinical trials, but a high-throughput approach is unlikely to be feasible for *in vivo* tests. Typically, researchers evaluate the drug efficacy in *in vivo* animal models, such as mice, by simply comparing the change in tumor volume between treated and untreated controls. However, these comparative studies can be complicated by the errors simultaneously produced by inherent biological variations, low precision of measurement tools, as well as limited sample sizes. It will be desirable to develop new measurement tools capable of accurately predicting treatment response and tumor progression *in vivo*, based on high-resolution datasets that can transform the drug discovery process.

To fulfil this technological gap, a multidisciplinary research team led by **Prof. Zhenan Bao** leveraged their expertise in flexible electronics to design a wearable strain sensor that allows real-time monitoring of tumor progression, which is recently described in a publication on ***BioRxiv***. The sensor records the change in tumor volume every 5 minutes and can readily generate datasets to determine the pharmacodynamic response of a given drug within hours of therapy initiation. This technology is termed **FAST**, standing for Flexible Autonomous Sensors measuring Tumor volume regression (**Figure 1**).

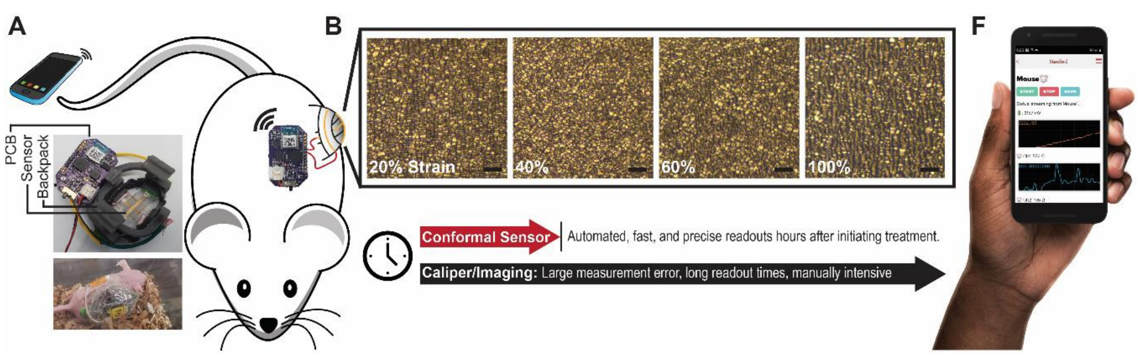

Figure 1. Illustration of the Flexible Autonomous Sensors measuring Tumor volume regression (FAST) technology. Image credit: Dr. Alex Abramson, Bao Group, Stanford U.

This FAST technology outshines other conventional tumor measurement techniques in three ways. First, the sensor can function during the entire measurement period without mechanical limitations or toxicity to living tissue. Second, the sensor is able to precisely detect small changes in tumor volume that might have been considered measurement error for calipers and bioluminescence imaging techniques. Last, the autonomous and non-invasive nature of FAST technology further enables large-scale preclinical drug screening in a rapid and inexpensive fashion.

Customizing a Wearable Strain Sensor

The FAST sensor is fabricated by depositing a 50 nm layer of gold metal over a polymeric layer of styrene-ethylene-butylene-styrene (SEBS). After wrapping around a tumor, this flexible and stretchable sensor can readily expand or shrink with the tumor as its size changes. When the sensor is stretched by tumor growth, the conducting gold layer forms micro-cracks resulting in an exponential change of electrical resistance in response to applied strain and a high measurement resolution of length to 10 µm. Notably, this sensor can not only tolerate large mechanical strain up to 200 %, but also regains its original conductivity when relaxed to a lower strain.

The FAST sensor can be integrated with electric circuits and cell phone apps to display live data and past data, and the whole device can be powered by batteries. The researchers validated both the high accuracy and precision of the sensor using known resistors, and the measurement errors were determined as only 1-2 %. Moreover, the team created a stretchable housing for FAST using 3D printing to ensure the sensor functions robustly even when the device is attached to the skin of moving mice.

Lead author, Dr. Alex Abramson (left) and team leader, Prof. Zhenan Bao (right).

Tracking the Dynamics of Tumor Growth *in Vivo*

The next step for the researchers was to carry out *in vivo* testing using mice models implanted with human cancer cells and test the effects of an orally dosed drug (Erlotinib) whose pharmacokinetics and pharmacodynamics are known to occur within hours. As expected, an initial test of the sensor placed on growing, untreated tumors obtained increased resistance that directly reflected tumor progression, which quantitively matched with other measurement techniques like calipers.

Immediately following administering drugs for therapy in mice, the FAST sensor was able to capture small changes in tumor volume between the treated and the untreated groups in only 5 hours. In contrast, other techniques such as bioluminescence and measurement with calipers were unable to discern any statically significant difference within the same period, due to their large measurement errors. When wearing the sensor, the animals can still maintain their regular biological activities such as moving and eating. Further histological evidence supported that tumor shrinkage was solely due to the drug pharmacodynamics, while the presence of the sensor on the skin negligibly affected tumor growth. Lastly, the effectiveness of the FAST sensor was tested and validated for other *in vivo* animal models and with other treatment parameters, revealing its high potential for versatile applications in future therapeutics.

Overall, the authors demonstrated a wearable strain sensor system that can track the dynamics of *in vivo* tumor growth autonomously, continuously, and accurately. The high resolution of this FAST technology allows initial assessment of the efficacy of potential drugs for cancer therapeutics, by gauging primary tumor regression in a short period of time (5 hours). For *in vivo* preclinical trials, this method can supplant current tumor regression measurement techniques and open up new avenues for high-throughput screening for drug discovery.

Source Article: Alex Abramson, et al. "A flexible electronic strain sensor for the real-time monitoring of tumor progression." bioRxiv (2021).

The **eWEAR-TCCI awards for science writing** *is a project commissioned by the* **Wearable Electronics Initiative (eWEAR)** *at Stanford University and made possible by funding through eWEAR industrial affiliates program member Shanda Group and* **the Tianqiao and Chrissy Chen Institute (TCCI®)**.