Real-time monitoring, control, and management of liquid flows enabled by novel flow sensor technology

TENDO
.technologies

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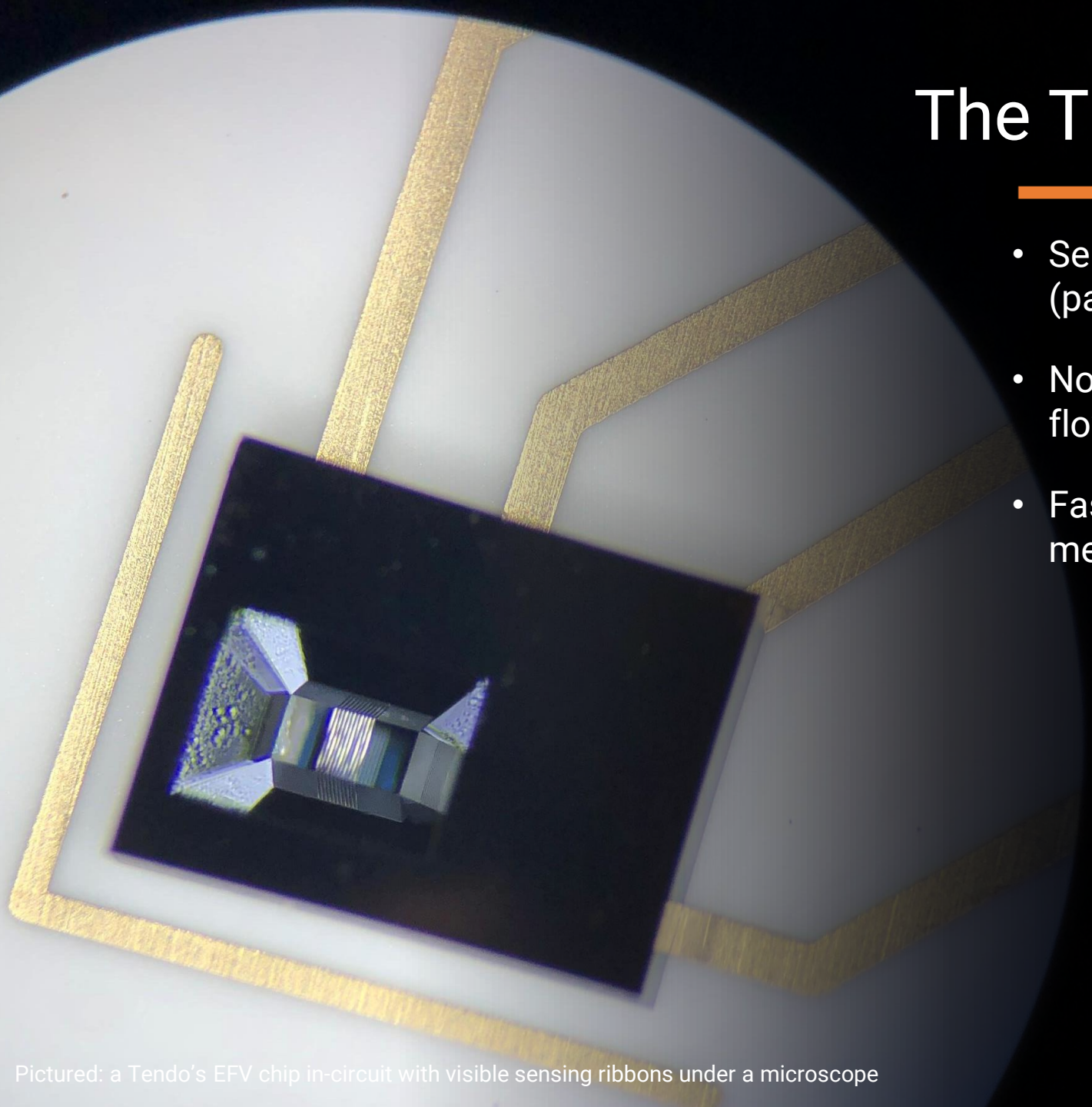
Many industries revolve around precise **mixing and dispensing** of liquids

- Fragrances and flavors (F&F) production
- Pharmaceutical/vaccine manufacturing and packaging
- Compounding pharmacies
- Infusion monitoring
- Laboratory processes
- Surface coating and paint
- and many more…

About our business

- **Tendo's Mission**: Develop the next generation of liquid-based dispensing and manufacturing applications with our patented flow measurement technology.
- **Team**: 50+ years of experience in fluid, hardware, and semiconductor engineering
- Surgically targeted business case with large impact: transforming liquid dispensing applications with our novel, patented technology
- Technology intense, but capital light
  - Partnerships that partially fund R&D activities
  - Secured suppliers to reduce cost



The Tendo Difference

- Semiconductor based, US patented technology (patent-pending in EU, China, & India)
- Novel sensing mode using the deflection of an in-flow ***nanoribbon*** design to measure flow rate
- Fast responding, allows for real time flow rate measurements and feedback

Sensitive

Versatile

Scalable

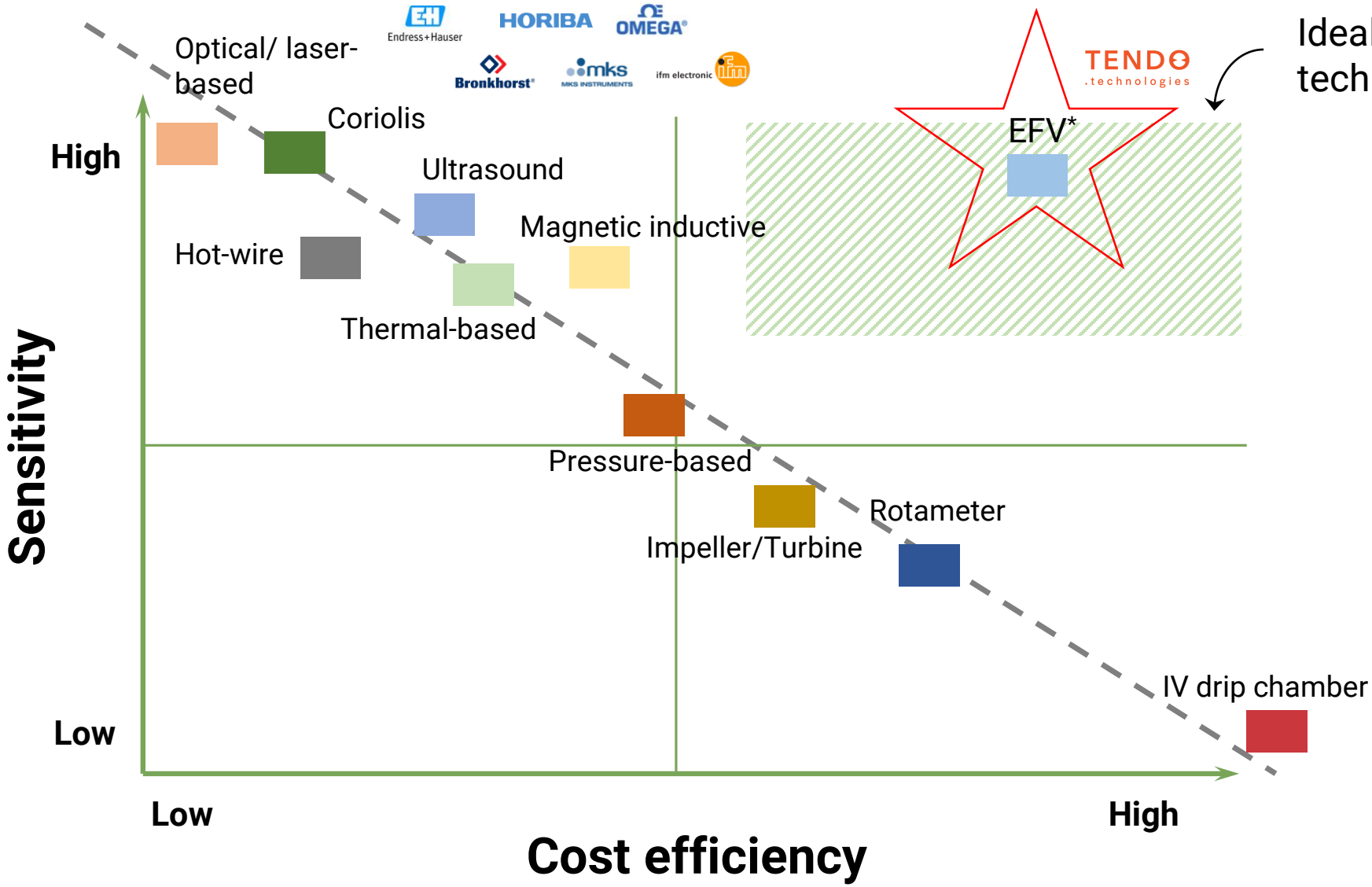
Compact

High viscosity fluids

Excellent material compatibility

Flowrate/Temp 2-in-1

Pictured: a Tendo's EFV chip in-circuit with visible sensing ribbons under a microscope



Technology Comparison

for various flow sensing methods

* Elastic Filament Velocimetry, Tendo's patented cornerstone flow sensing technology

Values that Tendo can bring

Fragrances and flavors (F&F) production

- Enable parallelized dispensing with 20x increase in factory throughput
- Provide an economical avenue for factory automation which reduces human error

Pharmaceutical/vaccine manufacturing & packaging

- Real-time dosage measurements to speed up certain vial-filling processes that are currently restricted using slow-responding weighing scales
- Disposable sensors to reduce equipment sterilization time and cost; but compatible with cleaning and sterilizing methods for reprocessing

Infusion monitoring

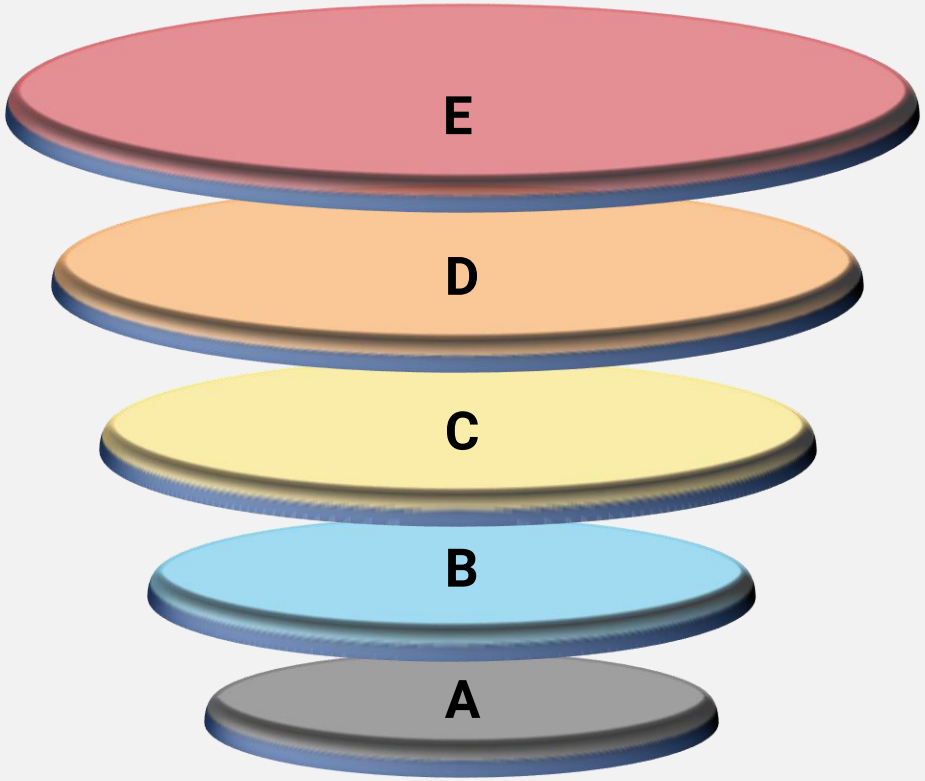
- Direct, real-time measurements of infusion rate that can detect malfunctions (air bubbles, pressure buildup due to kinking/blockage in tubing) and occlusion, reduce dosage errors during the processes, bring extra level of safety to patients
- Disposable tube set/syringe-level sensor comes pre-sterilized, can enable wired/wireless connectivity with other devices, and reduces manual data input errors by nurses or patients

Product stack layers – same core sensor, application-specific wrappers

The Foundation: Semiconductor based sensing chip — **A**

Communication: Operating and comm. circuitry — **B**

Packaging: Application-specific packaging/housing — **C**



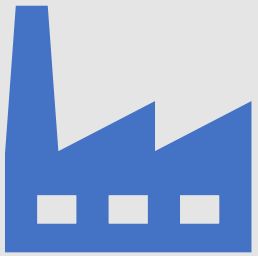
D — **Controls**: Hardware + software controller to go beyond measurement

E — **System**: Multiple individual devices to perform application-specific tasks

Example applications:	Disposable medical device	IoT / medical monitoring	industrial & pharma mfg.
	A	**B**	**C** **D** **E**

Use case 1 – parallel dosing

Liquid-compounding factory manufacturing



Problem

Process Manufacturing Factories

Med/Pharma Compounding Factories

Automated factories
High labor cost regions

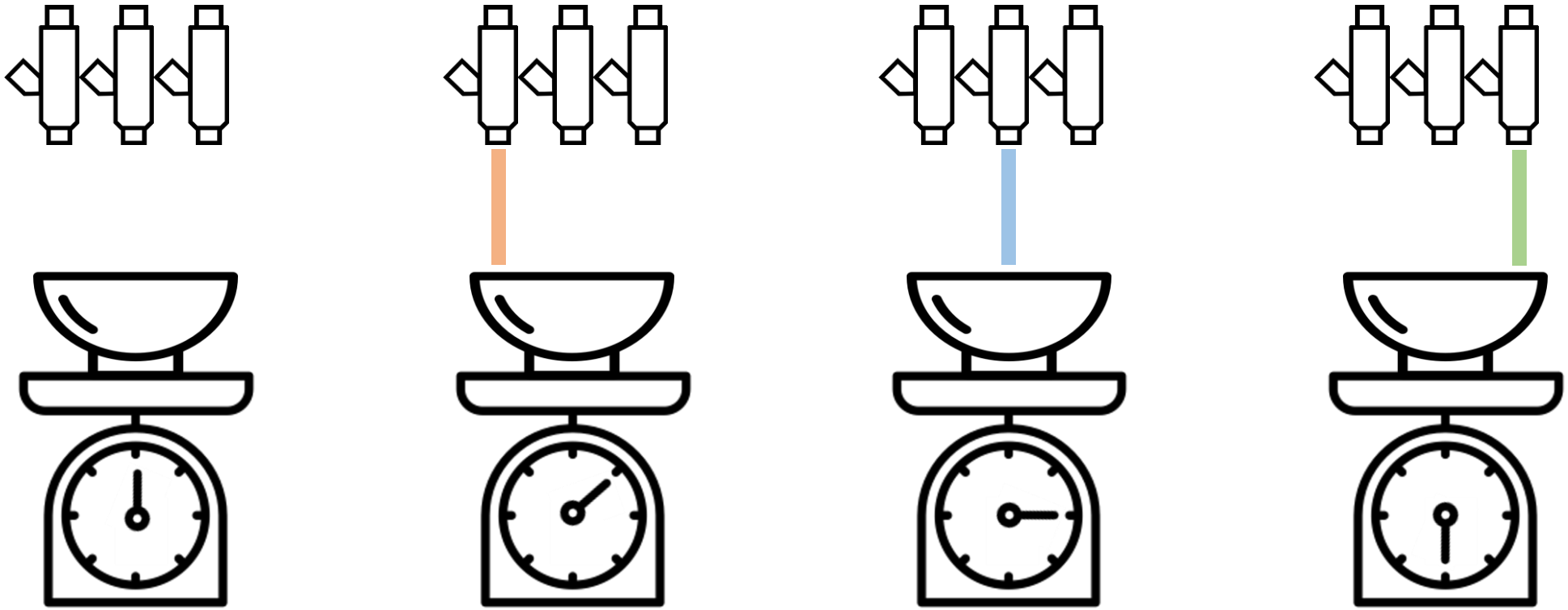
Manual factories
Low labor cost regions

Revenue growth is limited due to **insufficient factory throughput**

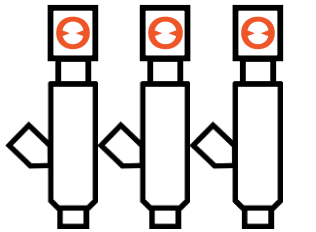
Human errors remain costly, factory automation unachievable due to **high automation cost but same throughput**

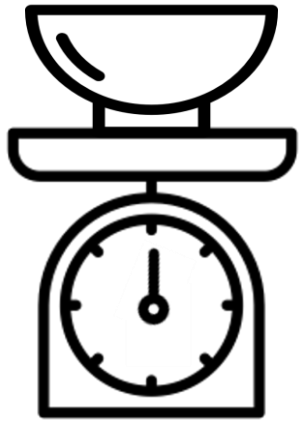
The only adequate current technique is the old-fashioned **sequential dispensing**

Sequential dispensing

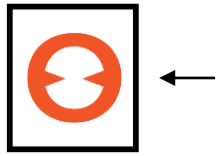


Tendo: enables parallel dispensing





Tendo is creating a flow metering unit to fit onto each dispense line, to monitor dispensed fluid in real-time



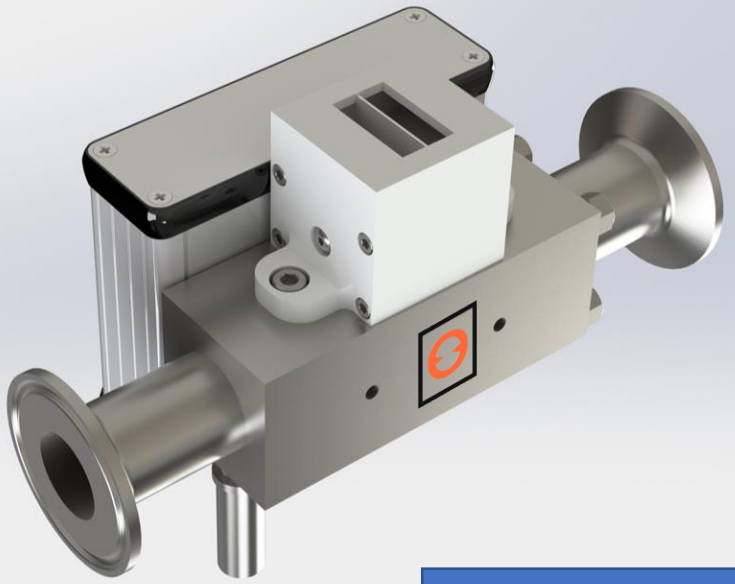
Tendo's flow metering unit

The Tendo unit enables:

- Inline flow measurement
- Real time feedback
- Cost efficient

Tendo will create a parallel liquid dispensing device enabled by its patented flow sensing technology for the fragrance and flavor factories, and later directly translate to adjacent industries

20x	Pour ingredients in a parallelized fashion, increase throughput by 20x
75%	Enable dispensing systems to reduce 75% footprint, generate even greater throughput
1/20	Our devices offer similar performance compared to high-end flow sensors, but only 1/20th the cost
	Economical solution to enable factory automation in low labor cost markets, reduce human errors and boost efficiency
	Software for automation optimization to improve process time



Pictured: rendering of Tendo's first flow metering unit for the fragrances & flavors application.

Ongoing co-development project in Fragrances & Flavors

- Working with a large F&F company to enable parallel pouring; starting with flow metering
- Tendo's flow units (enabled by our sensor technology) will be installed in their existing machines, at each dispensing point
- Partially funded R&D activities
- Include non-binding pre-order
- Provide expertise & factory pilot facilities

First milestones passed in Aug 2019 → In factory testing started Q2 2020 → Final milestones expected in Q4 2020

- Pharma manufacturing is the **immediate adjacent market**, therefore only minor design changes are needed, resulting in relatively short time to market

Stack C: Chip + Communication + Packaging

Exclusive license from Princeton Univ. ✓

TENDO .technologies ✓

Form a partnership and co-develop ✓

Pilot and sell to initial partner

Sell to other corporations

Use case 2 – real-time monitoring

Infusion therapy injection rate and doses

Problem

- >**1.5M** medication errors occur in the U.S. every year; >**$4B** [1] costs to the healthcare system
- Intravenous (IV) infusion errors pose **the greatest risk** of patient harm and are often life-threatening [2]
- Most important aspect of IV infusion is administering at the correct flow rate and dosage
- Infusion pumps were invented to regulate the infusion process but were not shown to significantly decrease the error rate [3]

[1] Aspden, P., et al. (2007). Institute of Medicine. Preventing medication errors.
[2] Dennison, R. (2006). American Nurse Today. High-alert drugs: Strategies for safe IV infusions.
[3] Westbrook, J. I., et al. (2011). BMJ quality & safety. Errors in the administration of intravenous medications in hospital and the role of correct procedures and nurse experience.

Constant volume pumps

- Infusion rate inferred from the turning of the motor
- Occlusions can raise infusion pressure, which can permanently damage tissues especially in young children

Constant pressure pumps (home use)

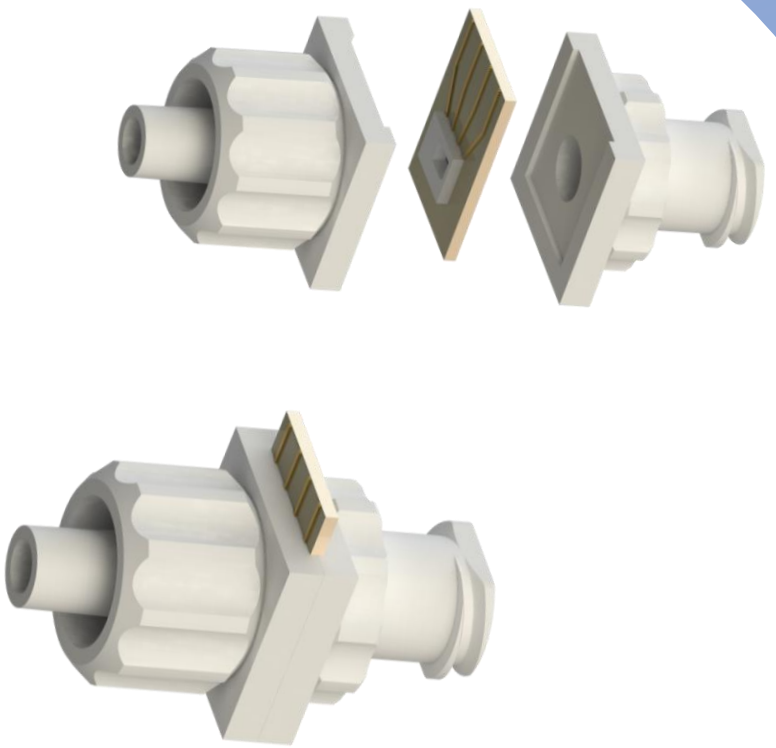
- Infusion pressure limited, which can prevent serious consequences from occlusion
- No direct or indirect method to infer infusion rate

Gravity-fed IV bags (with drip chambers)

- Inaccurate, and lack connectivity to integrate with nurse station systems
- Extremely price-sensitive; disposable flow sensor that meet this price point not available on the market

These problems can be solved with an **accurate**, **direct**, and **real-time** flow rate/dosage monitoring sensor that can also enable in-line pressure monitoring* (ILPM)

* Patent-pending: WO/2018/156707



Stack A Sensing chip only

Pictured: rendering of Tendo's disposable sensor in luer lock housing for healthcare applications.

Tendo's disposable inline flow sensors can provide real-time monitoring of IV and infusion lines

- Medical grade packaging, sensor sterilized
- Disposable, conformally coated with parylene
- Luer/barbed connectors, seamless interface with all systems at tube set/syringe level
- Economy of scale with semiconductor manufacturing processes (unit cost)
  - $12 – 1,000 sensors
  - $2.5 – 10,000 sensors
  - $0.5 – 200,000 sensors
  - $0.1 – 20,000,000 sensors
- Separate circuit with data processing and wireless/wired connectivity
- Can integrate separate chip-level memory for storing calibration information (ASIC)

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Team Tendo

- Co-founders are also co-inventors of the underlying tech
- 50+ years of experience in fluid mechanics, engineering, and semiconductor design & fabrication
- 35+ years of international business strategy experience with advanced tech companies

Marcus Hultmark, PhD

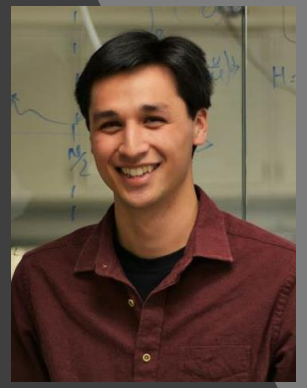
Co-founder

Yuyang Fan, PhD

Co-founder

Andrew Wagner

Engineer



Matt Fu, PhD

Co-founder & advisor

Steve Snyder

Business mentor

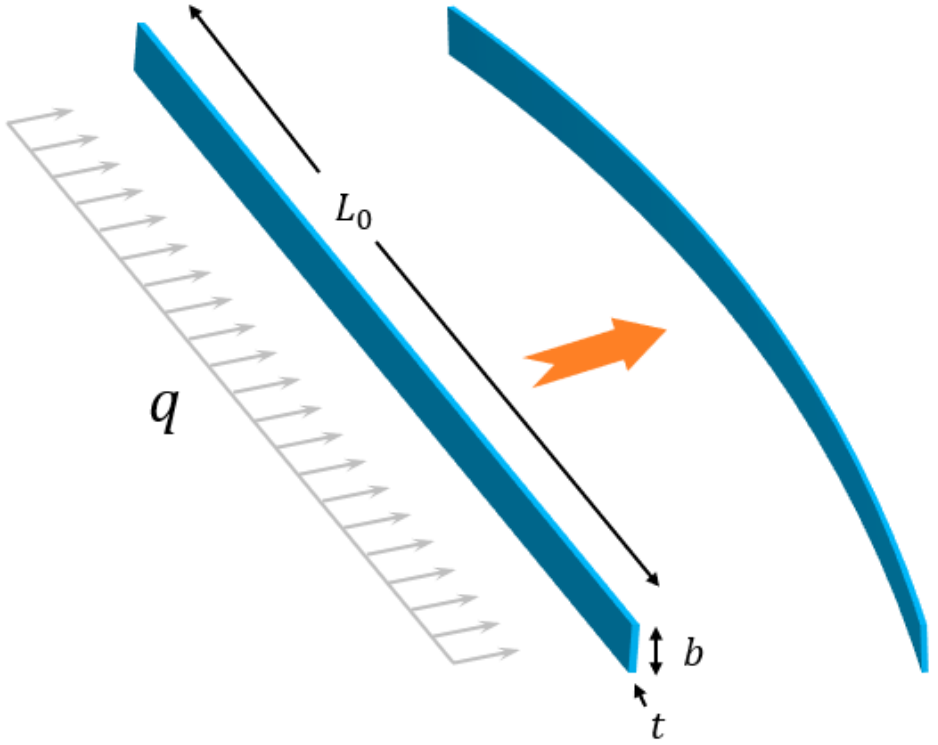
Countless verticals and other applications with Tendo’s flow sensing technology

- HVAC flow monitoring, distribution, and control
- Injection site monitoring (of medical devices) to ensure safety and detect potential malfunction
- Beverage dispenser real-time measurement and feedback
- Aerospace fuel monitoring (launch vehicles)
- Filter health monitoring
- Many more…

Appendix

Operating theory

- Utilizing strain gauge type effect from the sensing ribbon material
  - High aspect ratio ribbons deflect under fluid forcing, causing ribbon elongation
  - Induced stain results in electrical resistance change (sensor material specific)
  - Resistance change captured from a Wheatstone bridge



From beam theory:

$$EI\frac{d^4w}{dx^4} - Ebt\varepsilon\frac{d^2w}{dx^2} = q \quad \longrightarrow \quad \varepsilon = \frac{1}{2}\left(\frac{qL_0}{\sqrt{3}Ebt}\right)^{2/3}$$

E: Young's modulus ε: Strain

$I = bt^3/12$ q: Loading from fluid force

If b is small,

$$such\ that\ Re_b = \frac{\rho U b}{\mu} < \sim 50,$$

$$q \approx \mu C_D U$$

$$\varepsilon = \frac{1}{2}\left(\frac{C_D \mu U L_0}{\sqrt{3}Ebt}\right)^{2/3}$$

Fu *et al.*, "Elastic Filament Velocimetry", Measurement Science and Technology (2016)