# An Integrated Flexible Wirelessly Rechargeable Li-ion Battery

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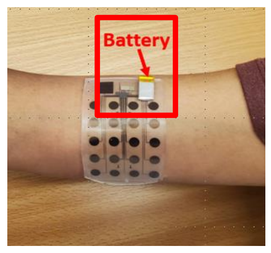
## Motivation & Introduction

- **Background**
  - Development of wearable device has been increasing rapidly in the past decade
  - The global pandemic has highlighted the need for continuous monitoring of physiological data
- **Motivation**
  - Current wearable devices uses Li-polymer battery, which is:
    - ✓ Thick & rigid package
    - ✓ Safety concerns
    - ✓ Unbalanced weight distribution

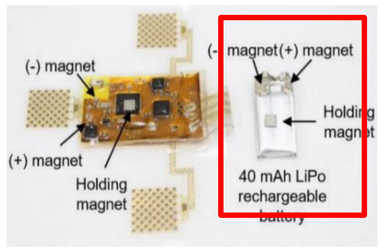
**Target specs of flexible battery for powering a sEMG 8 hours**

| Properties | | Target |
|---|---|---|
| Electrical & Mechanical | Total capacity | 60 mWh (18.2 mAh @ 3.3 V) |
| | Materials | $LiFePO_4$ / C |
| | Area capacity | 3.3 mWh/cm$^2$ (1 mAh/cm$^2$ @ 3.3 V) |
| | Output power | 10 (Average) / 20(Peak) mW |
| | Cycling life | 80% initial capacity after 200 times (1 year) |
| Mechanical & Geometrical | Bending radius | 5 mm |
| | Bending cycles | 1000 times |
| | Area | 20 cm$^2$ |
| | Thickness | < 500 µm |



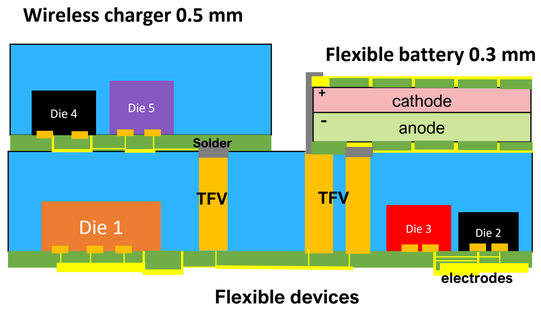

**sEMG @ UCLA CHIPS**
(Alam et al., 2020)


**ECG/EMG**
(Zhao et al., 2020)



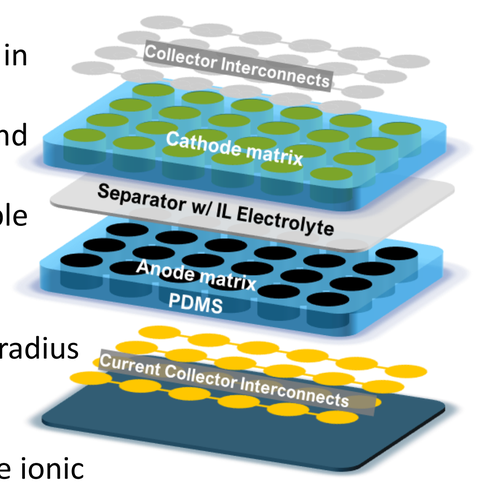

**ECG**
(Kim et al., 2019)

- **FlexPower: an integrated flexible wirelessly rechargeable Li-ion battery**
  - Flexible Li-ion battery
    - ✓ A battery integration scheme for flexibility with high area capacity density and output power
    - ✓ Safe for use in biocompatible applications
    - ✓ Wirelessly rechargeable
  - 3D Heterogenous integration of different flexible modules
    - ✓ Efficient use of space with three-D stacking of low form factor FlexTrate™



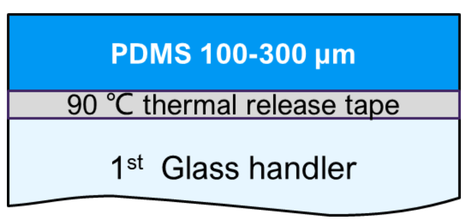

## Flexible Li-ion Battery Using "Battlet" Approach

- **Features of "battlet" battery**
  - Embedded cathode and anode cell matrix in PDMS substrate
  - Deposited flexible current collector and interconnects
  - Nonflammable electrolyte & Biocompatible encapsulation
- **Advantages**
  - Thin thickness (< 500 um) and 5 mm bending radius
  - High area capacity (> 1 mAh/cm$^2$) and output power (20 mW/cm$^2$)
  - Addressed safety concern using nonflammable ionic liquid electrolyte

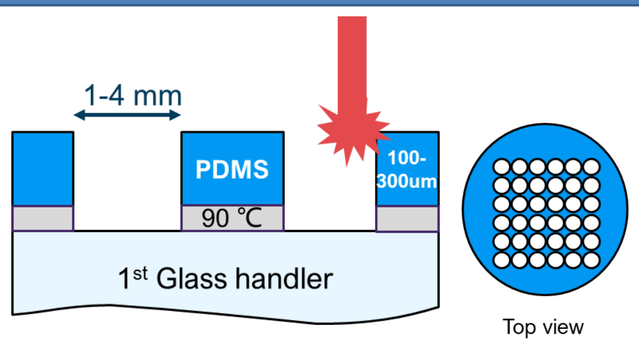



**Exploded view of battlet approach**

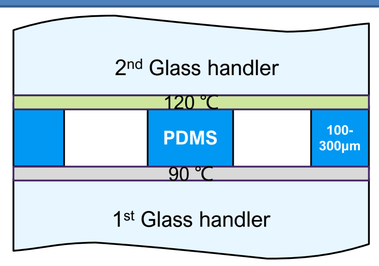
## Fabrication Process



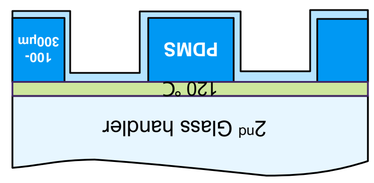

1. Spin-coating PDMS film



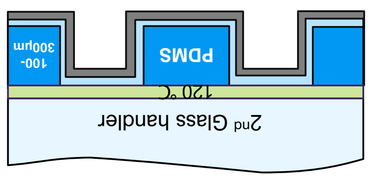

2. Laser-cutting Through PDMS Via matrix



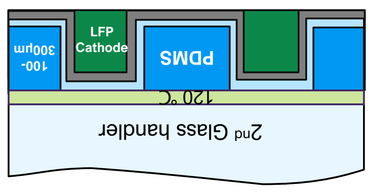

3 Transfering to 2nd handler



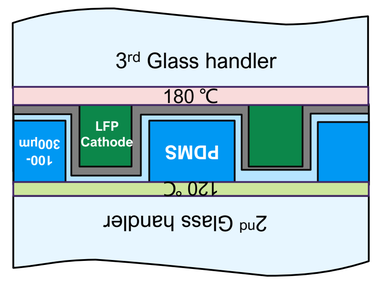

4 Release of 1st handler



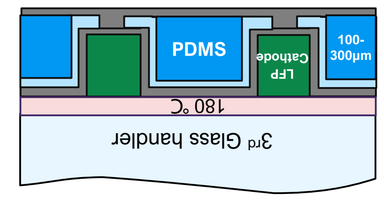

5 Deposition of Al layer



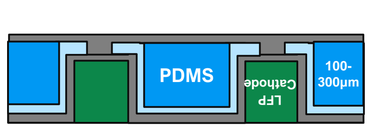

5 Filling and drying $LiFePO_4$ electrode slurry



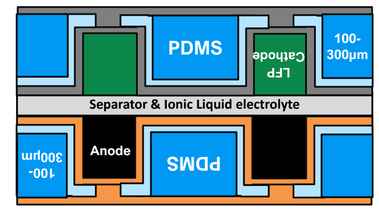

6 Placement of 3rd handler and release of the 2nd handler




7 Deposition of Al current collector 1um for LFP



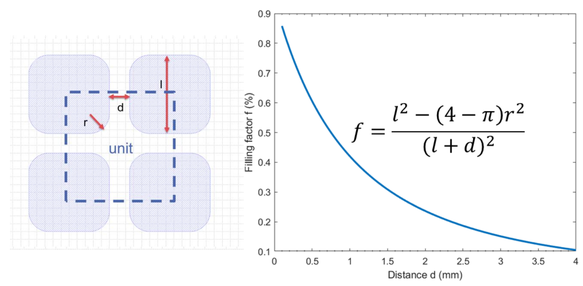

9 Release of substrate



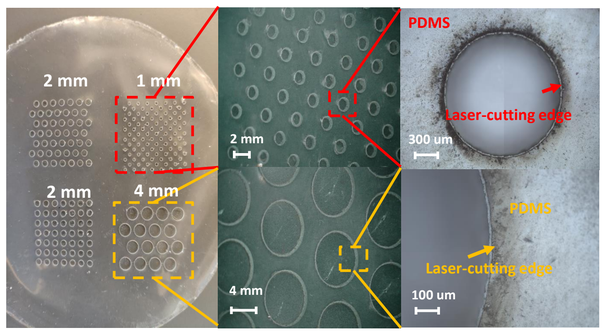

10 Using same way to fabricate anode and assembly

## Flexible Li-ion Battery –"Battlet" Design

- Improved active area, high utilize efficiency
- 0.5 mm radius (r)
- 2 mm length (l)
- 0.1-1 mm disk distance (d)
- Filling factor of unit cell is 0.4 - 0.86

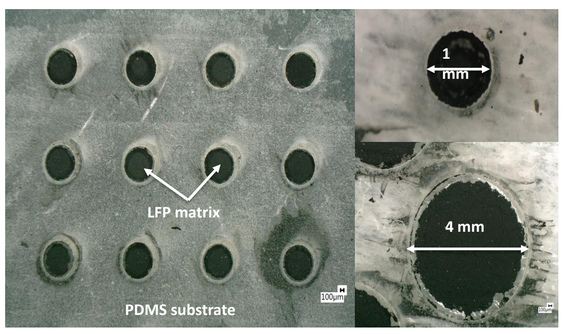



**Electrode Filling Factors**




**UV Laser Cutting of PDMS**

- 5W UV laser light
- Diameters from 1 ~ 4 mm
- Clean and sharp edges
- Can scale down to hundreds µm




**LFP Slurry Filling**

- Electrode thickness 100 ~ 120 µm
- Active materials loading density is 5-6 mg/cm$^2$ (~0.8 mAh/cm$^2$) in each cell

## Summary & Future Plan

- Completed design review of materials and performance requirement of FlexPower
- Developed and optimized the fabrication routine of flexible electrodes
- Setup battery assembly tools in the lab

| Tasks | 2021 Q3 | 2021 Q4 | 2022 Q1 | 2022 Q2 | 2022 Q3 | 2022 Q4 |
|---|---|---|---|---|---|---|
| Task 1: Design of experiment routine & Tool setup | Current work | | | | | |
| Task 2: Development of flexible Li-ion battery | | | | | | |
| Task 3: Development of flexible wireless charger | | | | | | |
| Task 4: Device integration | | | | | | |
| Task 5: Performance & reliability evaluation | | | | | | |