Next Generation Digital Microfluidic Technology for Efficient & Automated Transfection Experiments

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Accidental Observation in 2005

A 300 nL water droplet (1 mm diameter) under 3 kV/cm

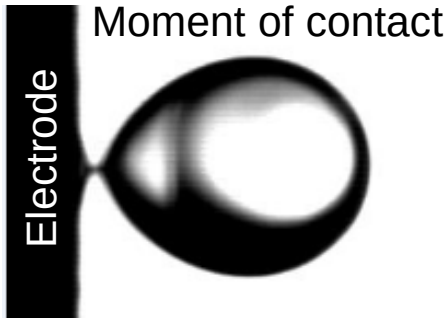
100 cSt silicone oil

Digital Microfluidic Feature

Electrophoresis of a **C**harged **D**roplet **(ECD)**

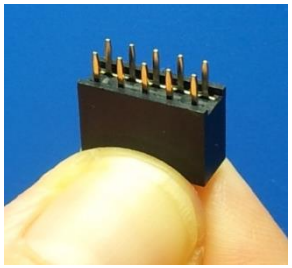
- **Simple and Straightforward**
  - **Easy to design electrodes**
  - **High degree of freedom in chip design**
- **Minimal solid surface contact**
  - **Suitable for biological applications**
  - **High reliability microfluidic device**
- **Fast droplet velocity**
  - **Fast and consistent droplet actuation**
  - **High analytical efficiency**

$$\mathbf{F} = Q\mathbf{E}$$

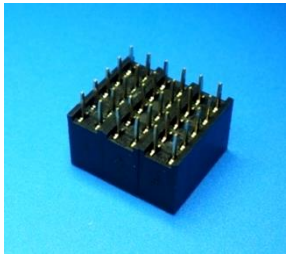


2011 National Futuristic Technology:
NTIS NO. 1345100479

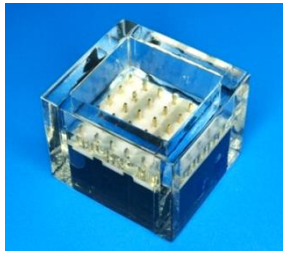
ECD based Digital Microfluidic System



Pin header socket

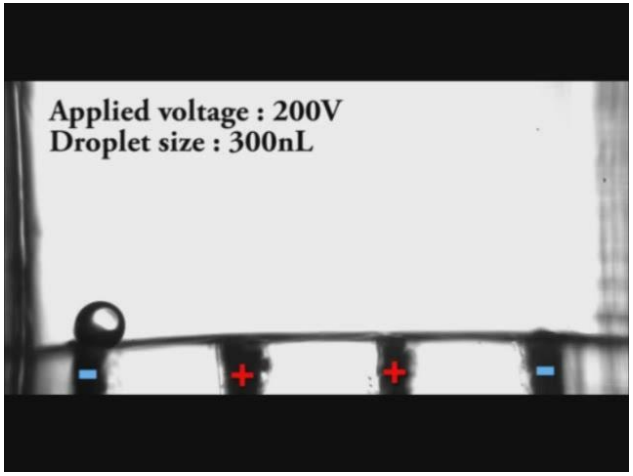


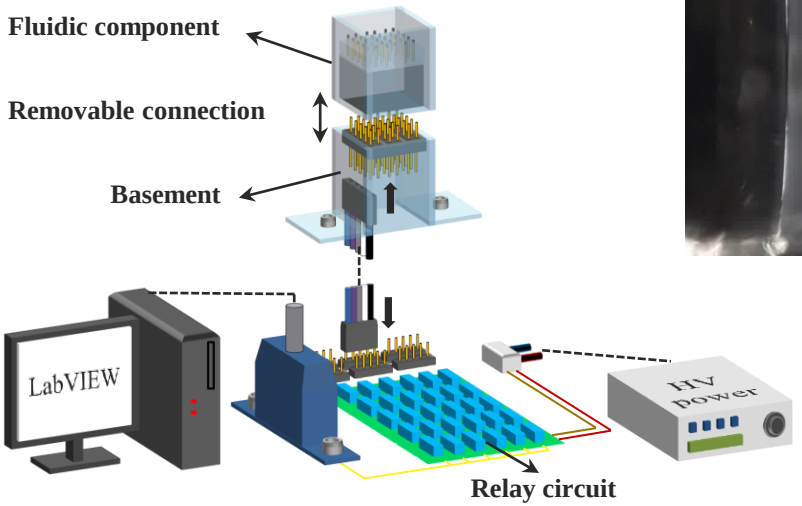
Assembly of electrodes



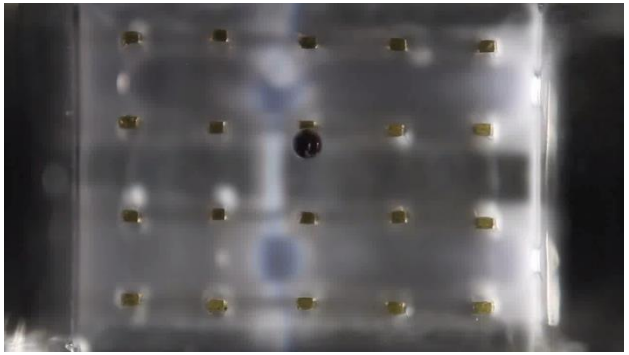
Fluidic component

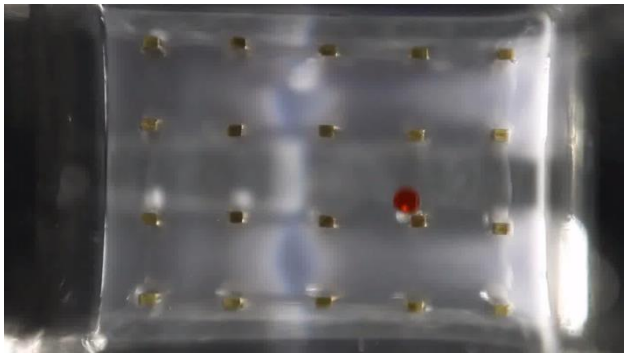
1D Translation





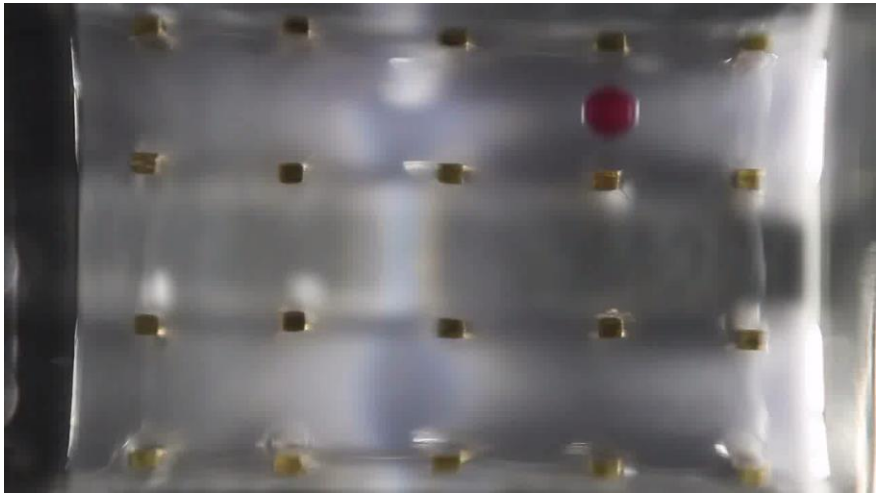
2D Manipulation

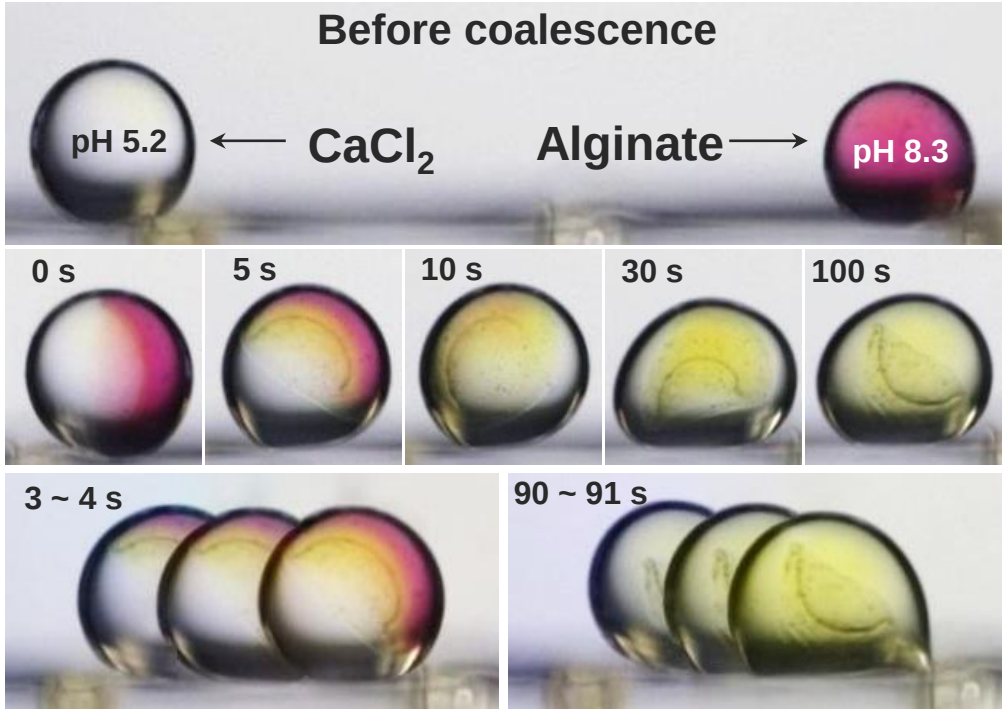




Alginate formation

Independent controls on the two droplets





✓ The interfacial tension changes as the gelation reaction proceeds!

Anal. Chem. 2013, **85**, 4038−4044

Digitial Electroporation - Motivation

✓ Synthetic DNA delivery systems

- Non-viral DNA delivery (transfection)
- Mechanical, Electrical, Chemical

✓ Electroporation (EP)

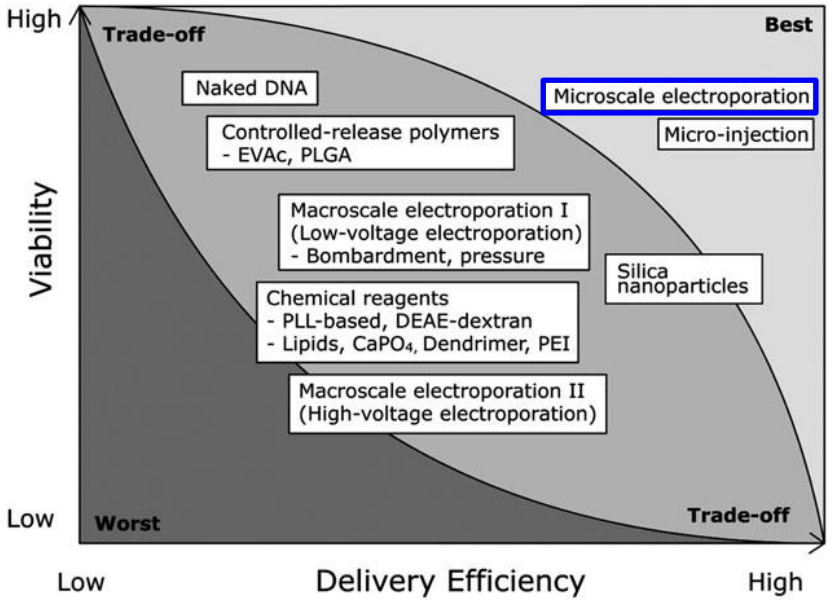
- Widely used, Good productivity
- Drawbacks of conventional EP

  : Low Viability, Contamination

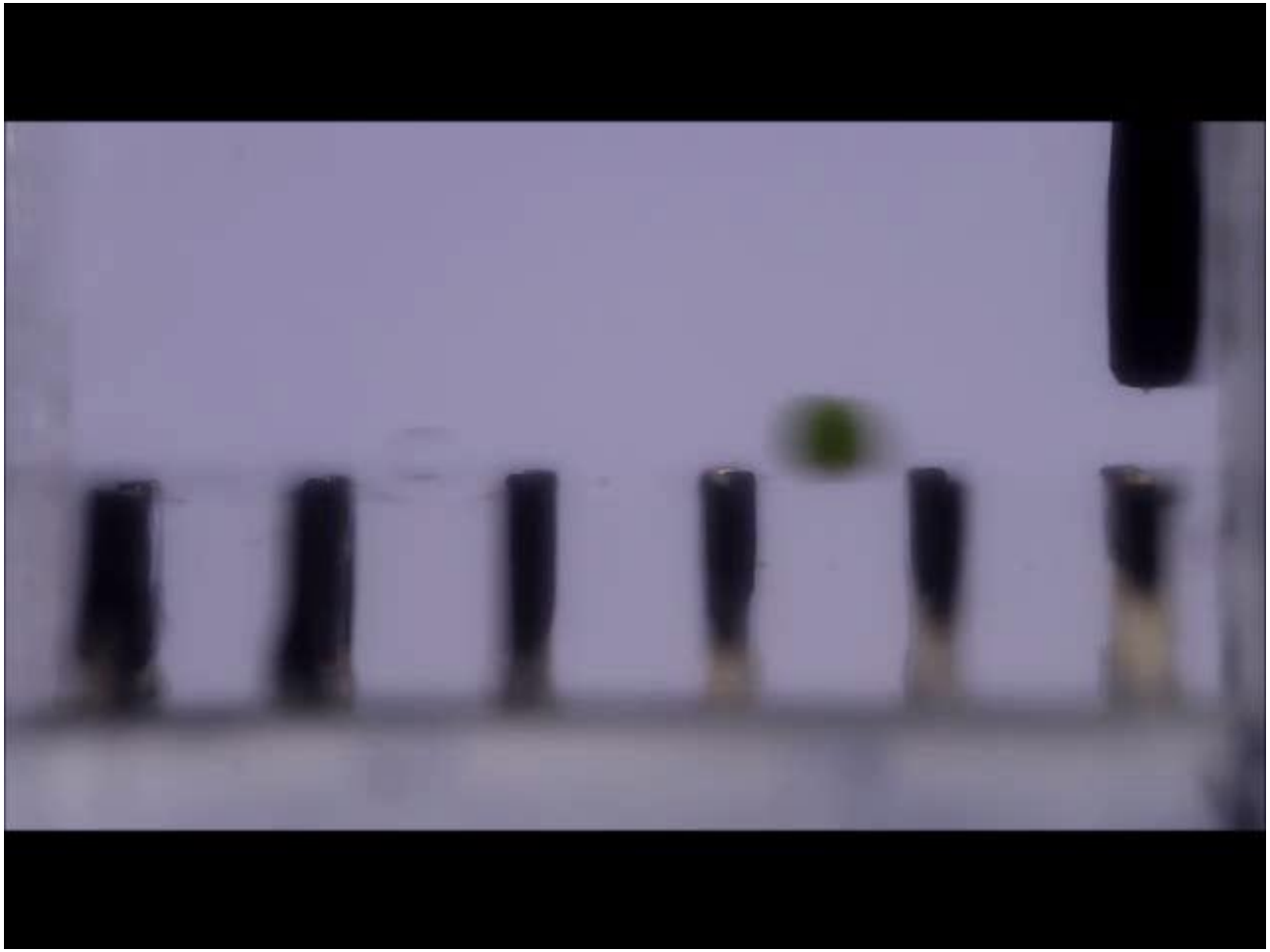
✓ Microfluidic Electroporation

- High cell viability and delivery efficiency
- Drawbacks of current microfluidic EP systems

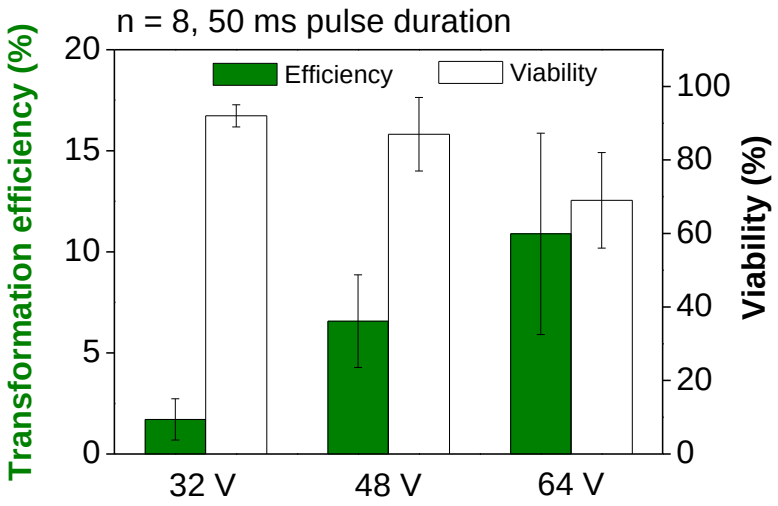
  : Lack of usability, Low productivity

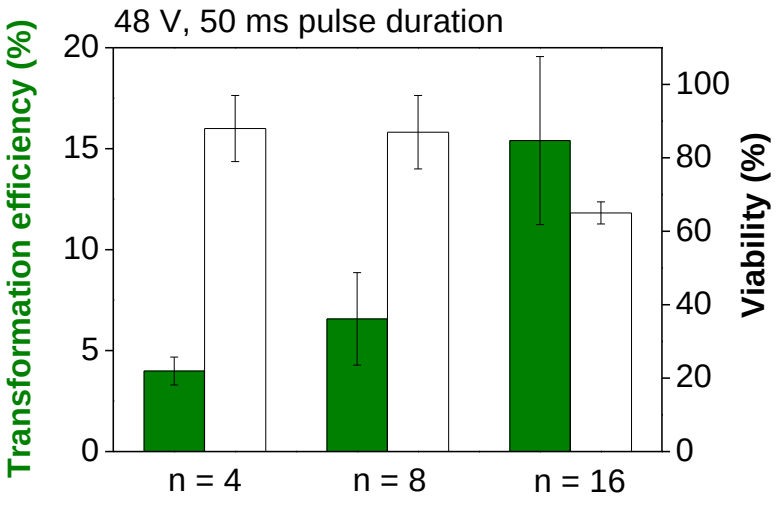


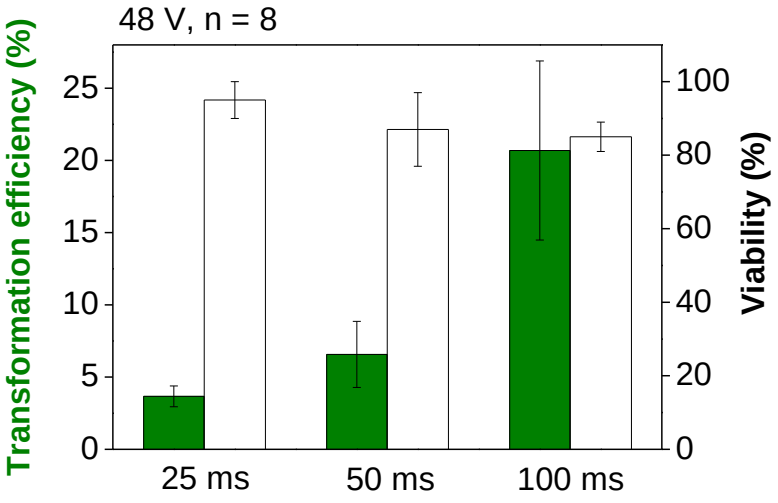
Integr. Biol., **2009**, 1, 242–251

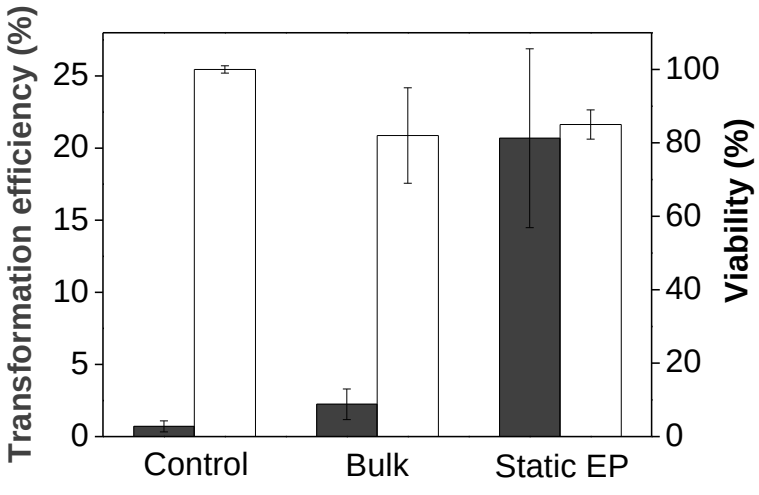


Algae transformation by Digtial EP

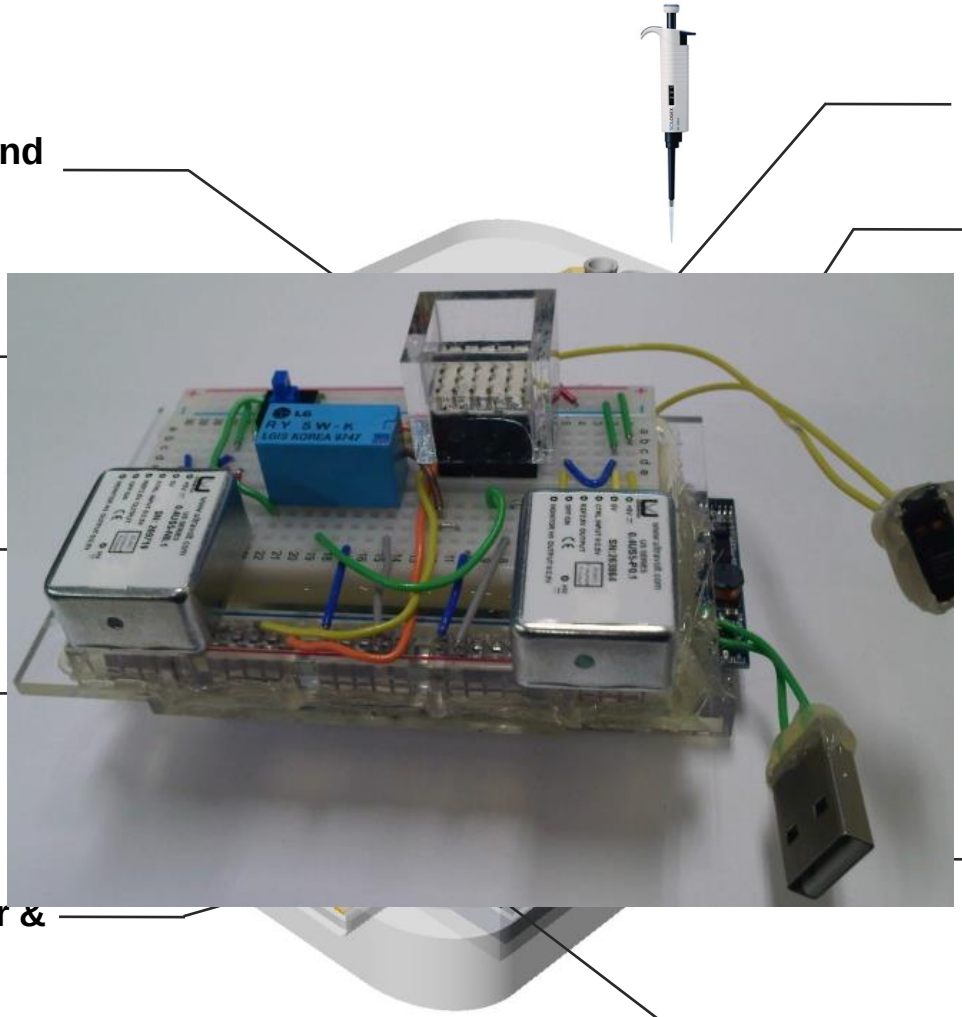








Integrated Cell Engineering Platform

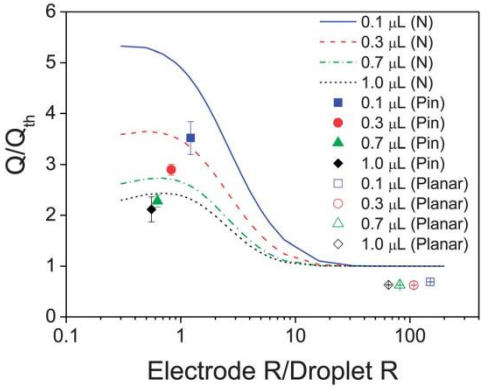


Input port/On-demand Dispensing Unit

Output port/ Splitting Unit

Display Panel

Optimal Electrode Design



Analyst 2013, **138**, 7362–7368

HV CMOS Relay

HV Boost Chip : 5 V → 500 V

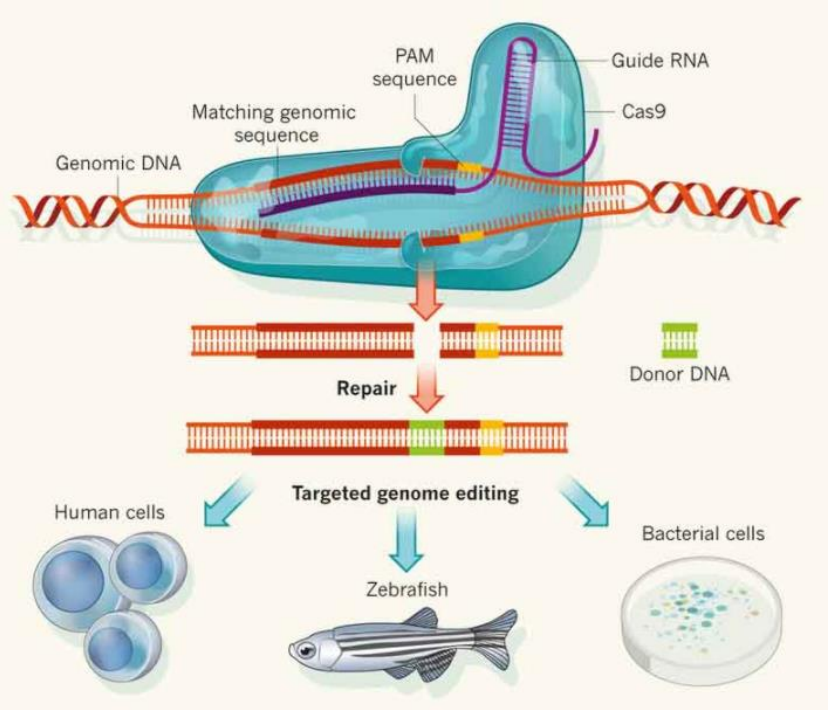
USB Port for External Power & Circuit Control

Rechargeable Battery

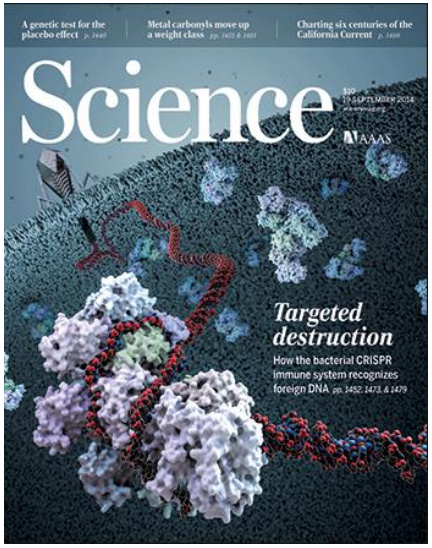
External USB Power/Battery Switching Module

Transfection Technology Trend

CRISPR-CAS9 Gene Editing



Guid RNA + CAS9 Protein
→ Delivered by **Electroporation!**



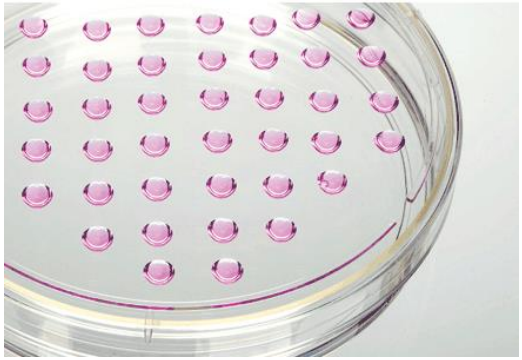
* CRISPR (**C**lustered **R**egularly **I**nterspaced **S**hort **P**alindromic **R**epeats)

Biomedical Application

Cell Engineering & Culture in a Droplet

✓ **Merits of droplet-in-oil environment**

- Small resource consumption
- Low contamination
- Increased gas exchange



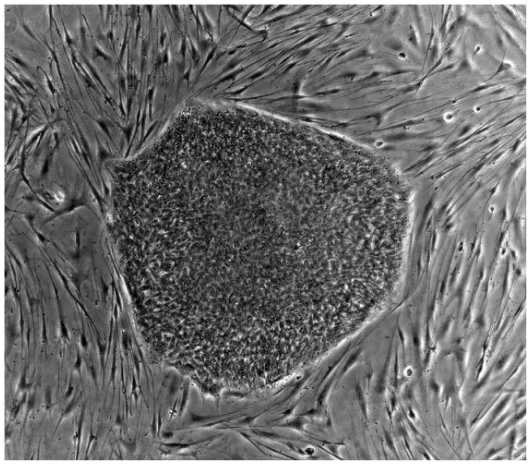
Hanging drop culture of embryonic stem cells
Nature Protocols 2011, **6** (7) Cover Page

✓ **3D cell culture**

- New paradigm of cell culture
- Close to real biological system

✓ **Digital EP for cancer & stem cell research**

- PI - NRF Project (No. 2013R1A1A2010483)
- Korean, PCT patents are pending



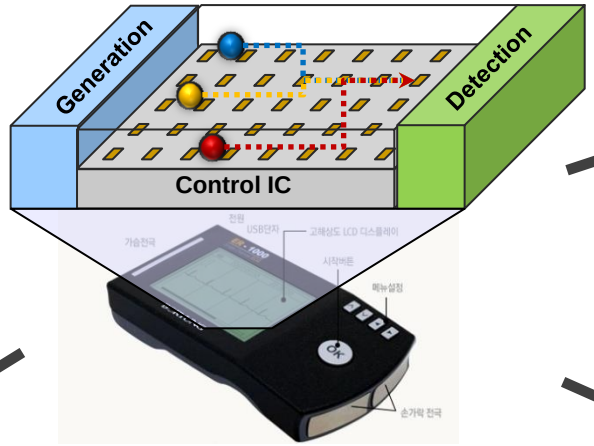
Stem cell culture

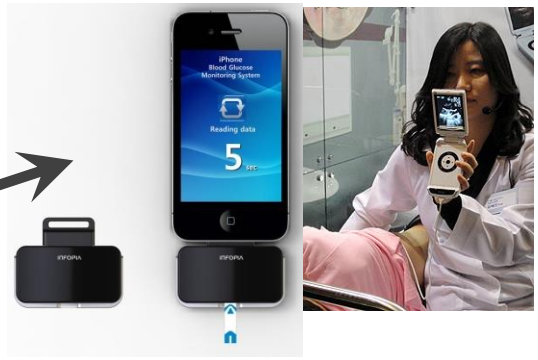
Application Area

Microfluidics + Electronics + IT Tech

→ Bio/Chemical Digital Microfluidic Applications

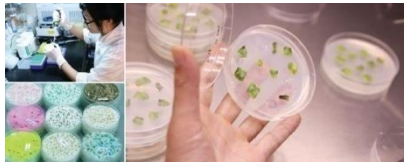
Portable DNA Analyzer



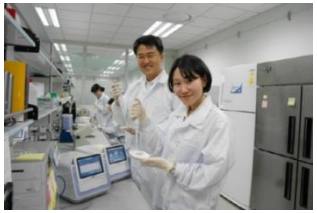


U-Healthcare

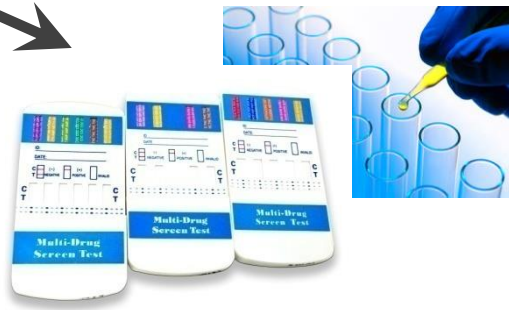
Portable cell culture



Life Science



Chemistry



Drug Screening