IO Rodeo

Open Hardware For Science Research & Education

Will Dickson & Jo Long

IO Rodeo Team

Jo Long

- Application Support & Community Development at IO Rodeo
- Background: PhD Biochem & Mol. Biology
- Research scientist: plant responses to the environment
- Educational technology

Will Dickson

- Software & Hardware development at IO Rodeo
- Hybrid between IO Rodeo & Caltech (instrumentation engineer)

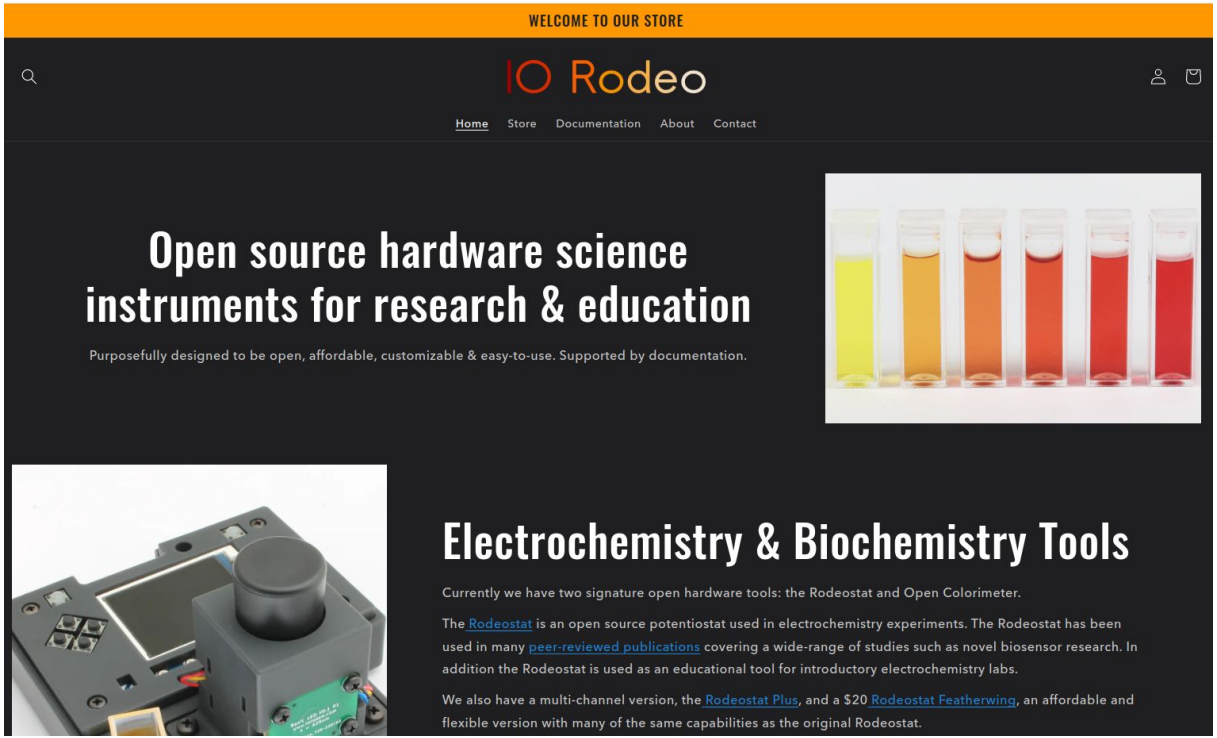
IO Rodeo

IO Rodeo

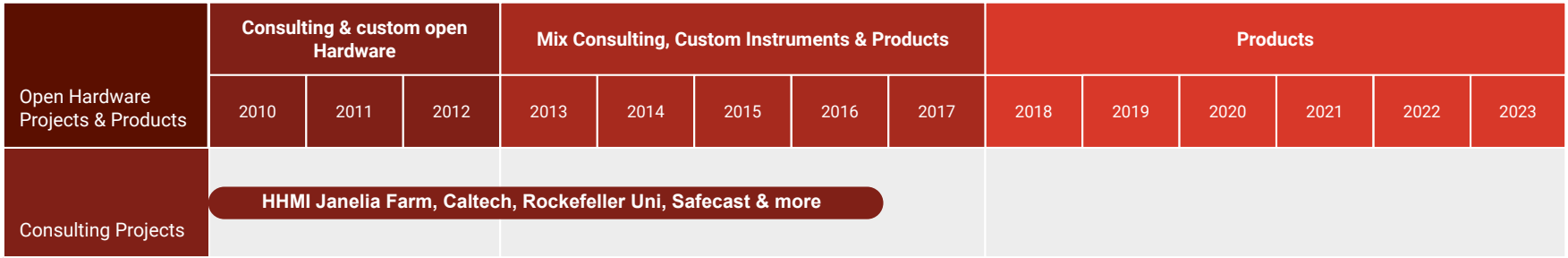
- Experienced limitations with using ‘black box’ instrumentation
- Recognized huge potential for open instruments in research and education
- Founded IO Rodeo in late 2009

Our Mission

Increase accessibility to scientific data collection tools by creating low-cost, open hardware instrumentation



Overview of IO Rodeo Journey



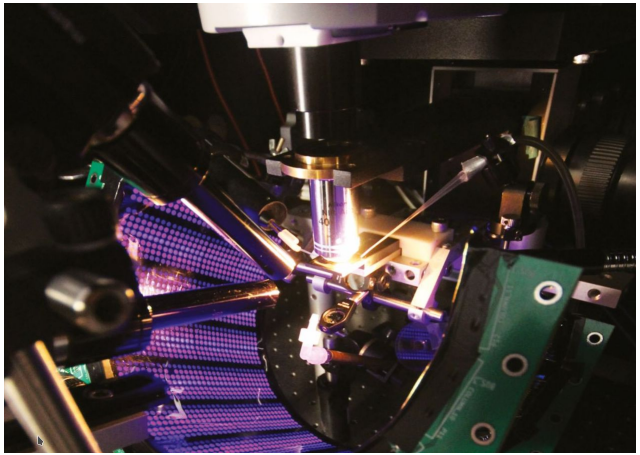
Started as consulting company (7 years)

- developed custom open source hardware instruments
  - behavioral arenas, real-time tracking, feeding sensors, stimulus

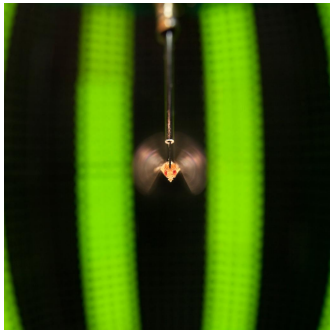
- Always planned to transition to products
  - low cost, accessible, open source scientific instruments

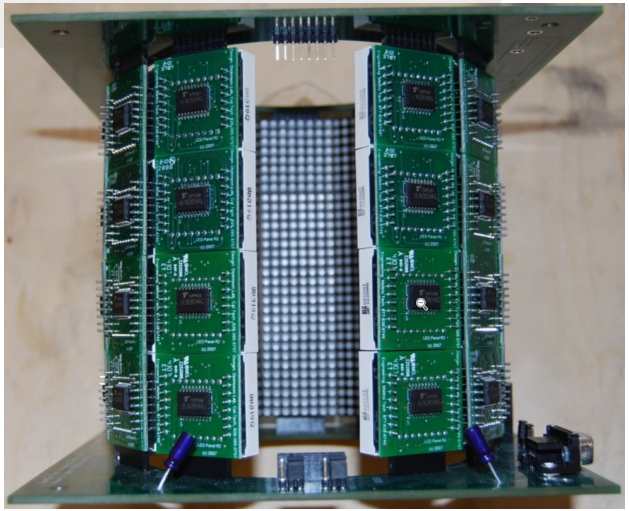
Overview of IO Rodeo Journey

	Consulting & custom open Hardware			Mix Consulting, Custom Instruments & Products					Products					
Open Hardware Projects & Products	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Consulting Projects	HHMI Janelia Farm, Caltech, Rockefeller Uni, Safecast & more													
Behavioural & Neurobiology Instruments		Panels Controller Display System												



Return to Caltech 50/50
Help Form Instrumentation Core
NIH Brain Initiative





IO Rodeo

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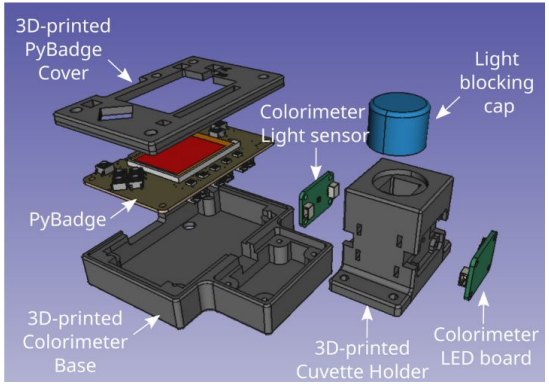
Behavioural & Neurobiology Instruments			Panels Controller Display System											
Colorimetry Products			(Kickstarter)	Educational Colorimeter Kit									Open Colorimeter	

- Began as a Kickstarter (11 years)
- Measure absorbance of light
- Originally Arduino based
- Recently redesign around PyBadge (Adafruit)
  - stand alone w/ display
  - battery powered



IO Rodeo

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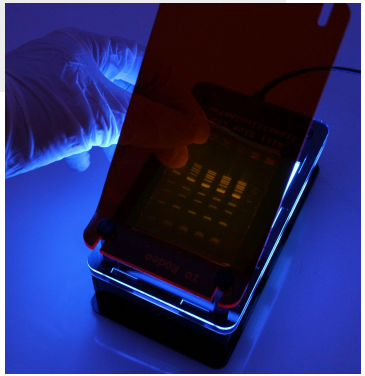
Colorimetry Products			(Kickstarter)	Educational Colorimeter Kit									Open Colorimeter	
Molecular Biology Products				Gel electrophoresis, Transilluminators, Power supply, Imaging enclosures										

- product line for 8 years
- supply chain issues
- focus on other products
- design files still available



IO Rodeo

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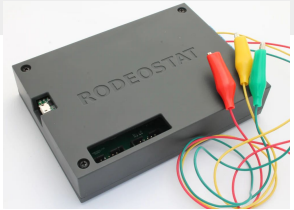
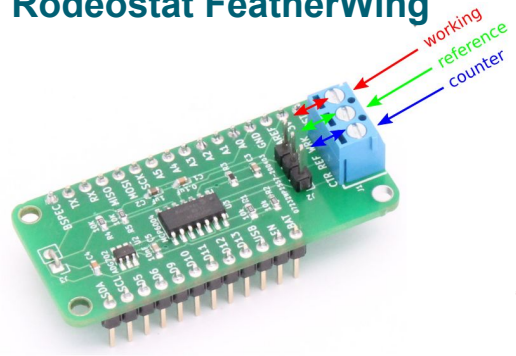
Molecular Biology Products				Gel electrophoresis, Transilluminators, Power supply, Imaging enclosures										
Electrochemistry Products							Cheapstat	Rodeostat, Multichannel, FeatherWing, SPE adapters						

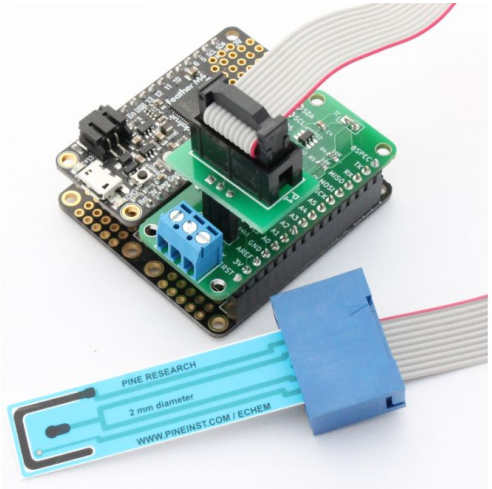
- Cover potentiostats in more detail in next slides



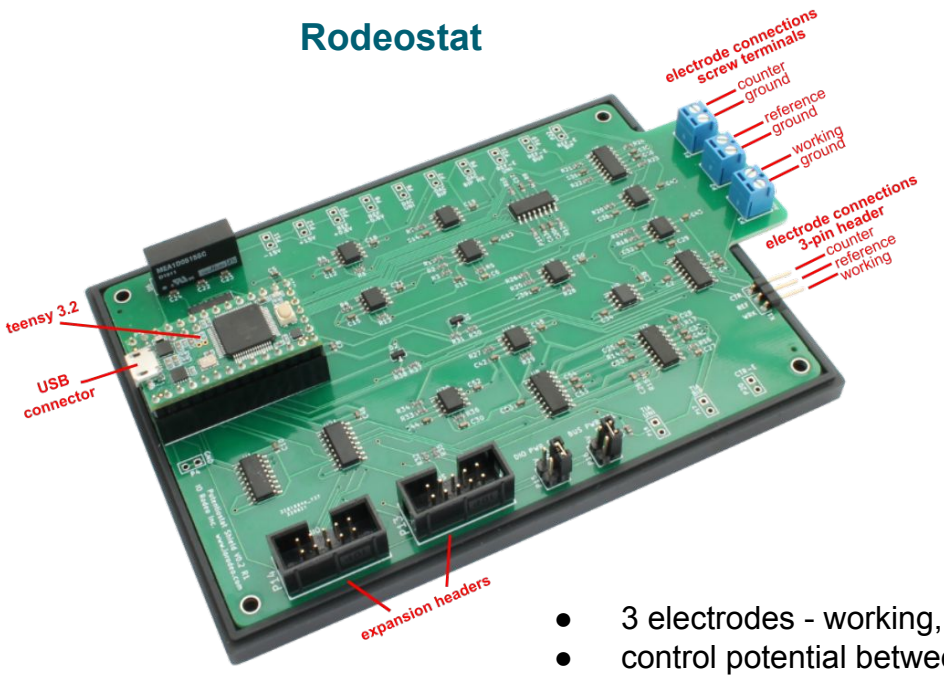
Electrochemistry- Open Source Potentiostats

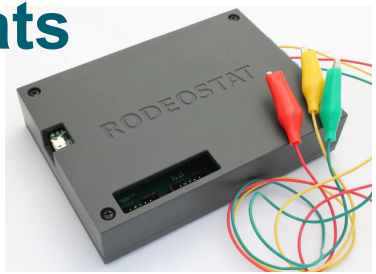
Rodeostat FeatherWing





Rodeostat





- 3 electrodes - working, counter, reference
- control potential between working and reference
- utilize feedback for control
- simultaneously measure working electrode current

Applications include:

- characterization of processes
- coatings and corrosion
- biosensor development

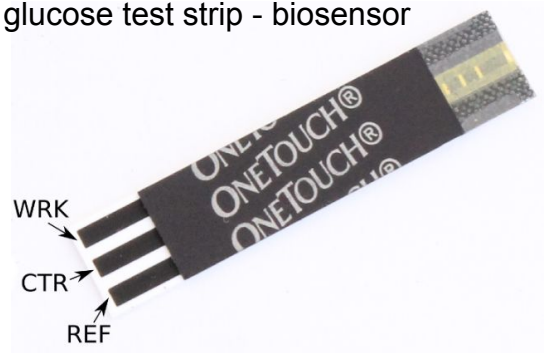
OSHW US002129

github.com/iorodeo/rodeostat_featherwing

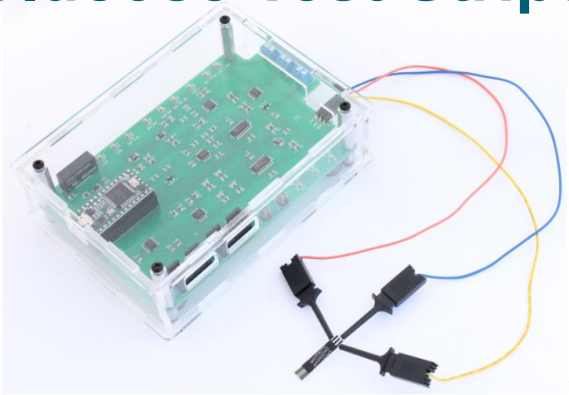
github.com/iorodeo/potentiostat

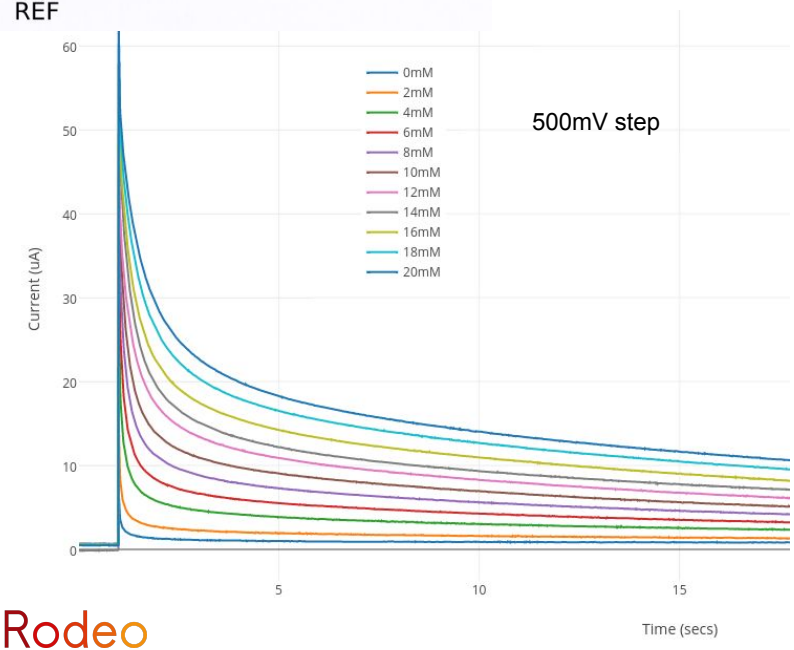
Chronoamperometry with Glucose Test Strips

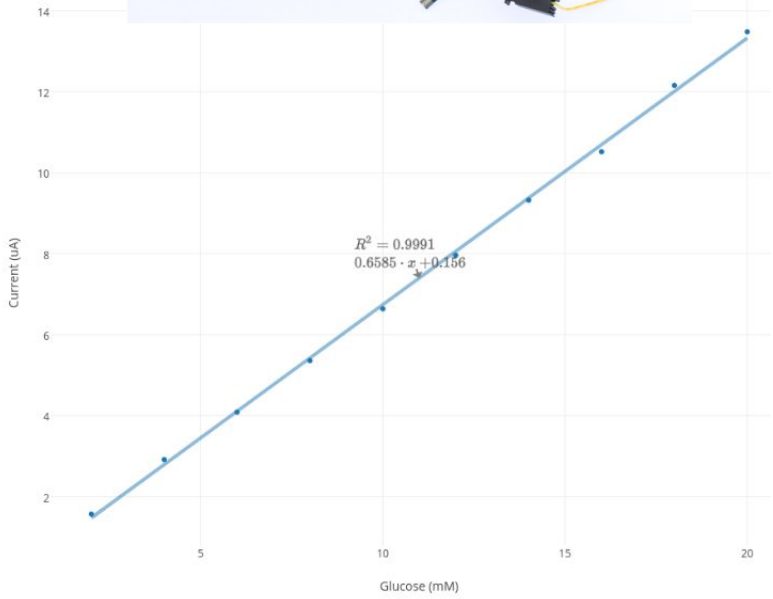
glucose test strip - biosensor



test strip contains the enzyme glucose oxidase (GOx) + electron transfer mediator







IO Rodeo

Open source software - programmable and customizable

Firmware (Arduino IDE)

Python library (scipy, numpy, matplotlib)

Lots of examples/tutorials

potentiostat - ps_circular_buffer.h | Ardu

File Edit Sketch Tools Help

Teensy 3.2 / 3.1

ps_circular_buffer.h ps_command_table.h ps_constant_te

```
1  #ifndef PS_CIRCULAR_BUFFER_H
2  #define PS_CIRCULAR_BUFFER_H
3
4  #include <Arduino.h>
5  #include "third-party/Array/Array.h"
6
7  namespace ps
8  {
9      template<typename T, size_t MAX_
10     class CircularBuffer
11     {
12
13         public:
14
15             CircularBuffer();
16             T& front();
17             T& back();
18             T& operator[](const size
19             T  operator[](const size
20             void push_back(const T &
21             void push_front(const T
22             void pop_front();
23             void pop_back();
24             void clear();
```

Ln 1, Col 1 UT

iorodeo-potentiostat

IO Rodeo

0.0.3

Search docs

- Installation
- Getting Started
  - Creating a device object
  - Getting list of voltametric tests
  - Getting voltammetric test parameters
  - Setting voltammetric test parameters
  - Getting/setting measurement current range
  - Getting/setting sample rate
  - Running voltammetric tests
  - Setting output voltage range
  - Manual/direct operation
  - Setting device identification number
- Multiplexer Exapansion Board
- Worked Examples
- Voltametric Tests
- API Reference
- Hardware Summary

Running voltammetric tests

Voltammetric tests can be run using the `run_t` voltammetry test you could do the following.

```
t, volt, curr = pstat.run_test('cyclic')
```

This method will return lists which contain the (uA) respectively. The test will be run with the for the specified test.

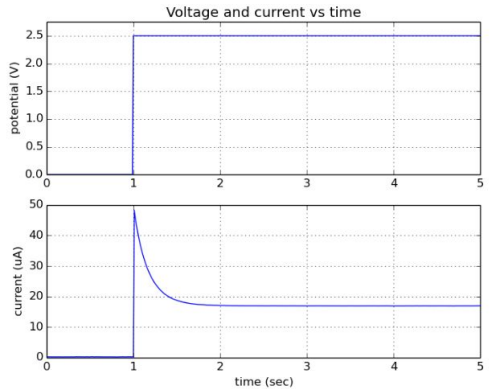
This method takes several optional keyword a to a file while the test proceeds you can speci

```
t, volt, curr = pstat.run_test('cyclic', fi
```

The *param* keyword argument lets you specify this case the parameter values will first be set run the test.

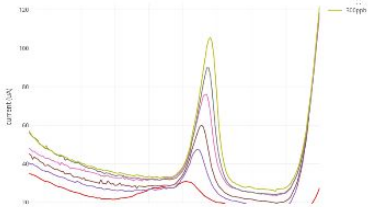
```
my_param = {
        'quietValue' : 0.0,
        'quietTime'  : 1000,
        'amplitude'  : 2.0,
        'offset'     : 0.0,
        'period'     : 1000,
        'numCycles'  : 5,
        'shift'      : 0.0,
        }

t, volt, curr = pstat.run_test('cyclic', pa
```

```
from potentiostat import Potentiostat
import matplotlib.pyplot as plt

port = '/dev/ttyACM0'    # Serial port for potentiostat device
datafile = 'data.txt'    # Name of output data file

test_name = 'constant'   # Name of test to run - constant voltage voltammetery
curr_range = '100uA'     # Name of current range for test [-10uA, +10uA]
sample_rate = 100.0      # Rate (samples/sec) at which to collect samples

test_param = {
        'quietValue' : 0.0,        # Output voltage during quiet peroid
        'quietTime'  : 1000,       # Duration of quiet period (ms)
        'value'      : 2.5,        # Output volatage (V) durring constant volta
        'duration'   : 4000,       # Duration of constant voltage test (ms)
        }

# Create Device object and set sample rate, current range and test parameters
dev = Potentiostat(port)
dev.set_sample_rate(sample_rate)
dev.set_curr_range(curr_range)
dev.set_param(test_name,test_param)

# Run cyclic voltammetry test
t,volt,curr = dev.run_test(test_name,display='pbar',filename=datafile)

# plot results using matplotlib
plt.subplot(211)
plt.title('Voltage and current vs time')
plt.plot(t,volt)
plt.ylabel('potential (V)')
plt.ylim(0,test_param['value']*1.1)
plt.grid('on')

plt.subplot(212)
plt.plot(t,curr)
plt.ylabel('current (uA)')
plt.xlabel('time (sec)')
plt.grid('on')

plt.show()
```



github examples/ + github.io

Example Projects & Tutorials



Tutorial

Bismuth modified carbon paste electrode for metal measurements

In the experiments described in this blog post, we made a bismuth modified carbon paste electrode...

Jun 14, 2018 · 4 min read

Tutorial

Making a carbon paste electrode

In this blog post we describe making a DIY carbon paste electrode using graphite powder/mineral oil...

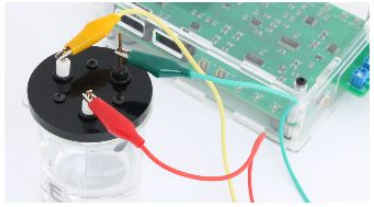
Nov 21, 2017 · 3 min read

Tutorial

Square wave anodic stripping voltammetry and metal testing

The Rodeostat python library has several electrochemistry programs currently implemented...

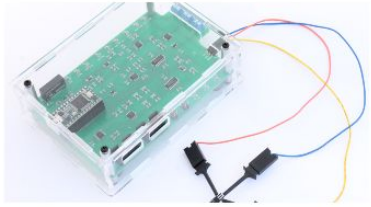
Oct 30, 2017 · 5 min read



Tutorial

Making a custom electrochemical cell

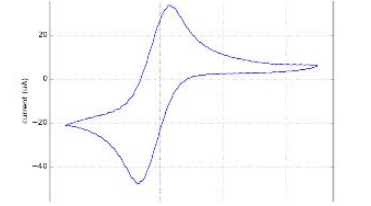
In this blog post we describe making a simple custom electrode mount that we used in cyclic...



Tutorial

Chronoamperometry with glucose test strips

In this electrochemistry experiment we used the Rodeostat...



Tutorial

Reversible Cyclic Voltammetry

In this blog post we carried out a cyclic voltammetry experiment with ruthenium hexamine Ru(NH3)6 a...

May 1, 2017 · 2 min read · 2 comments

Shipped Rodeostats to over 320 different cities

IO Rodeo

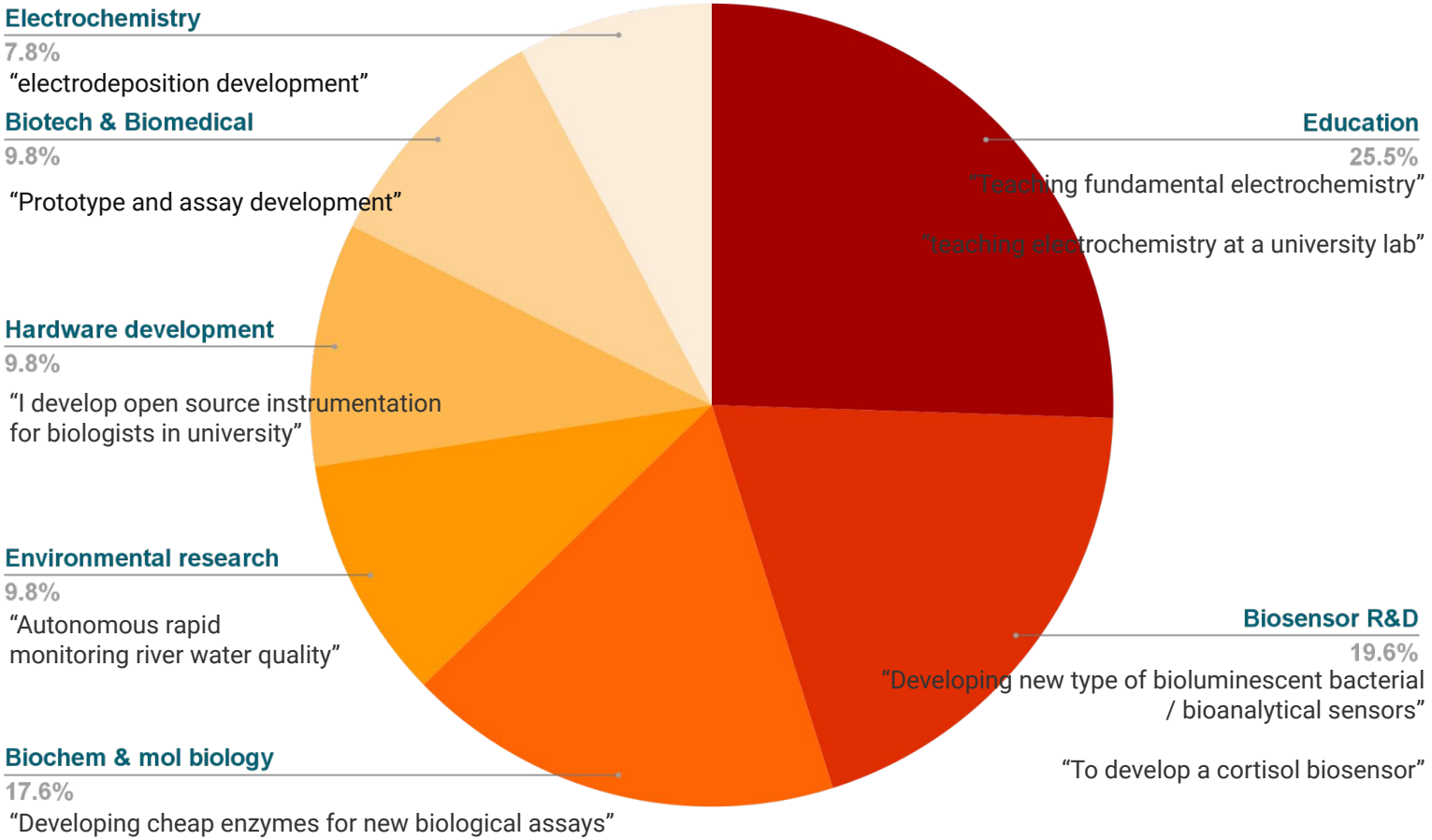
How & why our community uses open hardware science instruments

Photo courtesy of Adeline Seah, community science lab, Myanmar

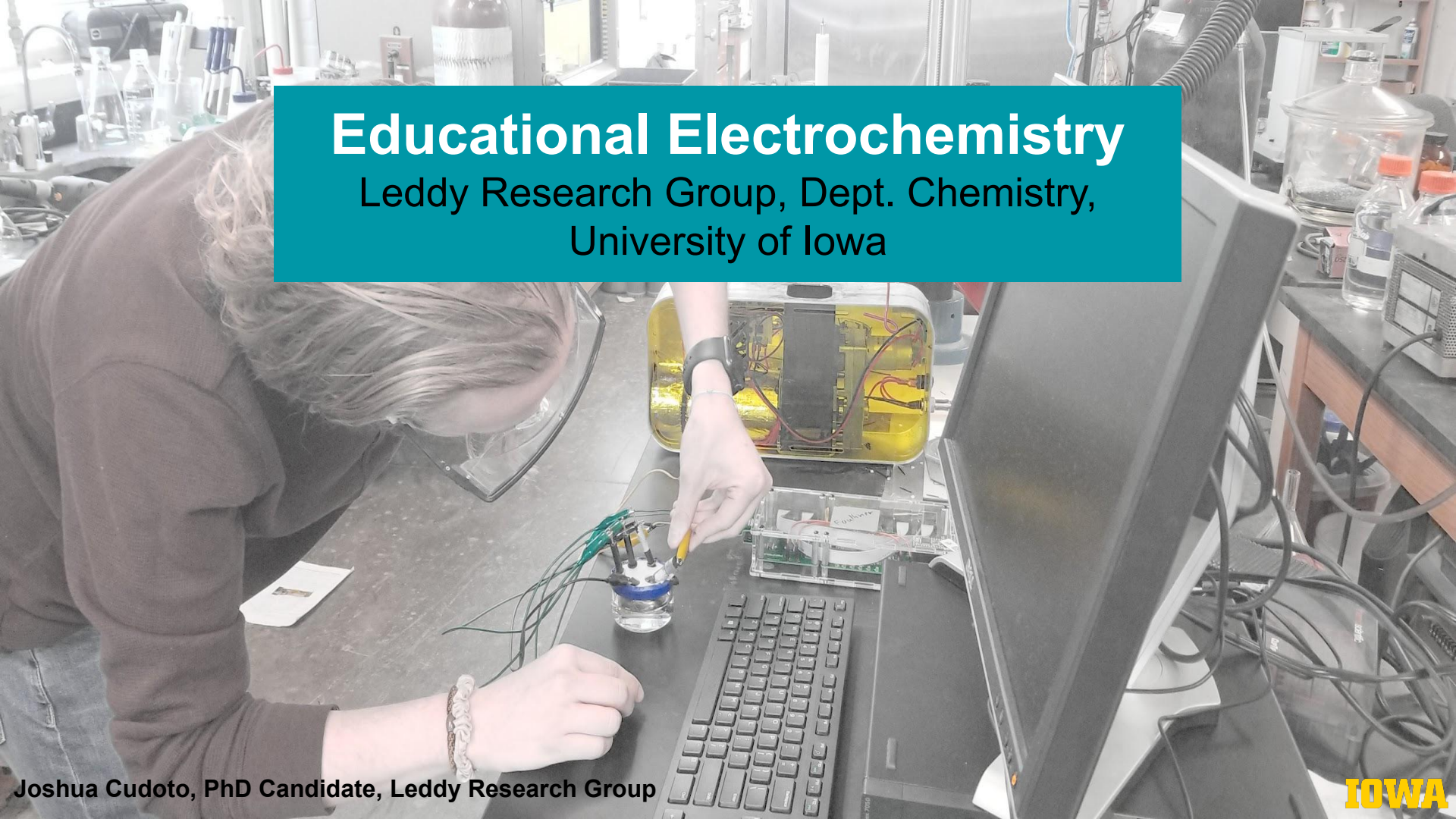
Photo courtesy of Josh Cudoto, University of Iowa

Photos courtesy of Karen Duca, USAID-sponsored Ghana Technician Training Workshop

Learning from the community about how they use open science instrumentation



IO Rodeo OSHW Survey, 2022



Educational Electrochemistry

Leddy Research Group, Dept. Chemistry,
University of Iowa

Joshua Cudoto, PhD Candidate, Leddy Research Group

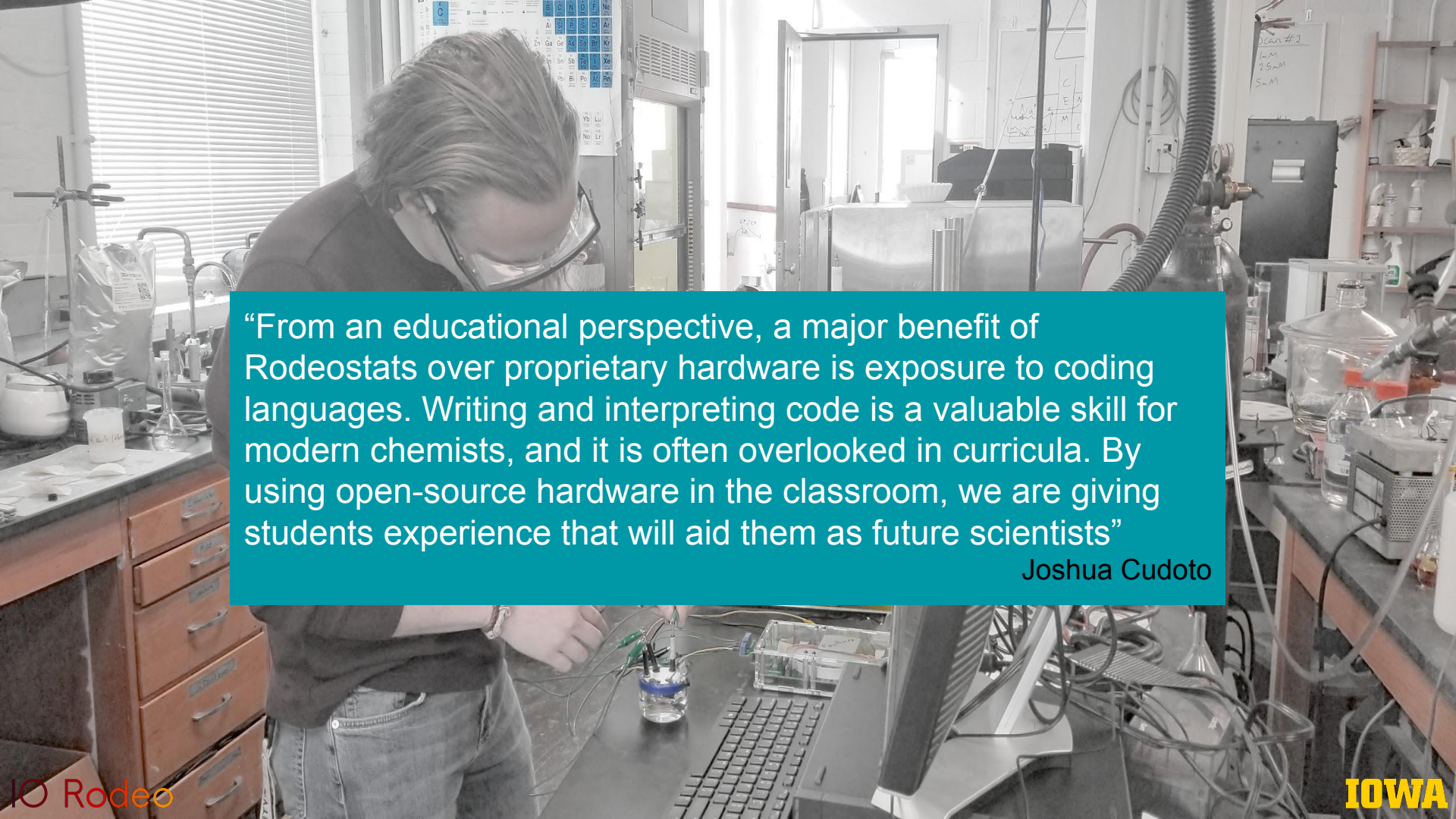
IOWA

"We chose the Rodeostat for our classroom because it offers flexibility and robustness. Being open-source hardware, instructors can better tailor experiments to match the learning outcomes of an experiment or course. In operating the instruments, students can execute provided scripts or build the operating code from the ground up. This makes the instrument suitable for both introductory and advanced courses, ranging from the basics of voltammetry to creating custom waveforms"

Joshua Cudoto

IO Rodeo

IOWA

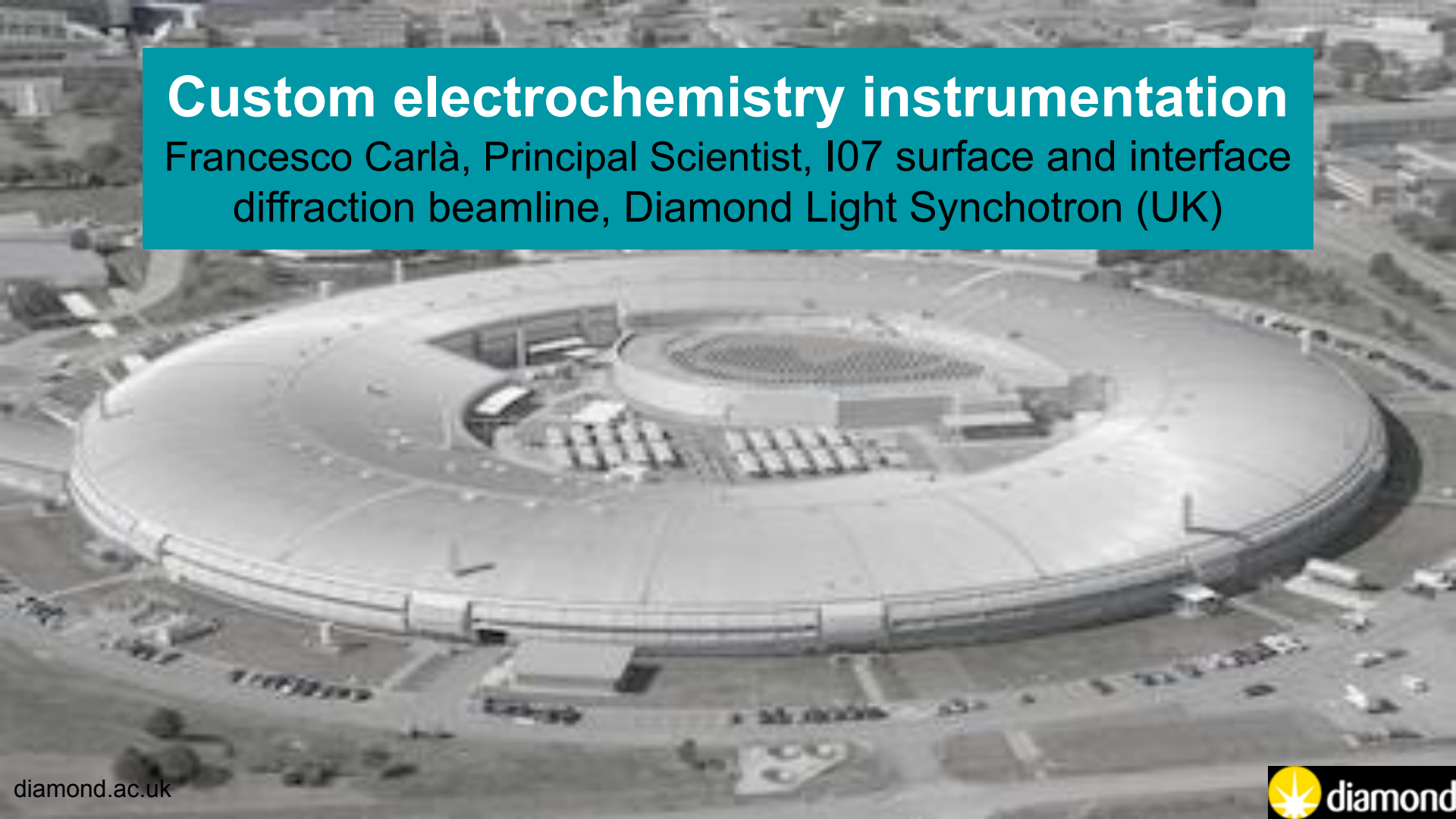


“From an educational perspective, a major benefit of Rodeostats over proprietary hardware is exposure to coding languages. Writing and interpreting code is a valuable skill for modern chemists, and it is often overlooked in curricula. By using open-source hardware in the classroom, we are giving students experience that will aid them as future scientists”

Joshua Cudoto

Custom electrochemistry instrumentation

Francesco Carlà, Principal Scientist, I07 surface and interface diffraction beamline, Diamond Light Synchotron (UK)



UK’s national synchrotron science facility, located at the Harwell Science and Innovation Campus in Oxfordshire.

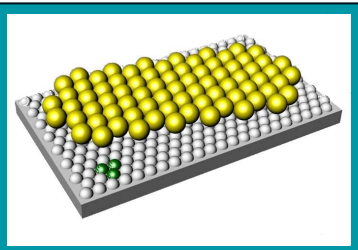
I07 is a high-resolution X-ray diffraction beamline for investigating the structure of surfaces and interfaces under different environmental conditions

Beamlines usually support complex experiments and the control software needs to be able to control multiple elements at the same time (x-ray detectors, diagnostic, motors, various type of electronics including potentiostat). **Due to the complexity of the experiments is necessary to be able to easily control the hardware**.

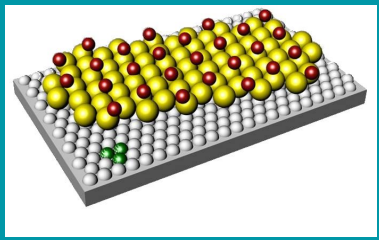
Electrochemistry experiments are normally focused on the topics of electrocatalysis, electrodeposition, corrosion and batteries

Electrochemical Atomic Layer Deposition (EC-ALD)

1) At I07 we are depositing CdS, exploiting the Cd2+ and S2- UPD reactions on Ag. The method is based on the alternate Underpotential Deposition (UPD) of the elements which form the compound.

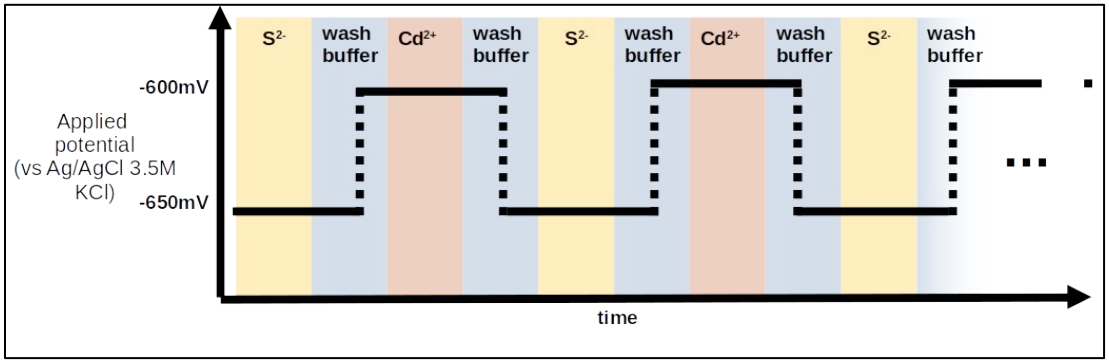


1st EC-ALD cycle (e.g. deposition of S^{2-} on Au)



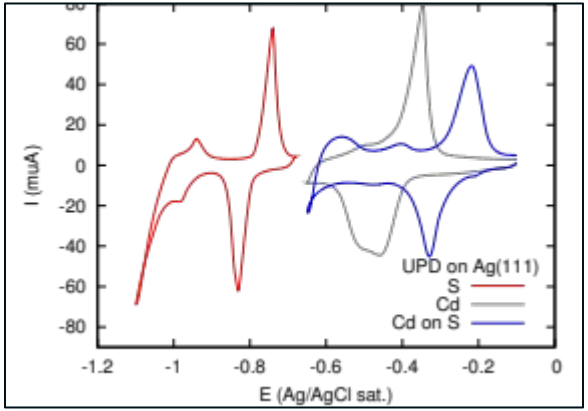
2nd EC-ALD cycle (e.g. deposition of Cd^{2+} on S/Au)

2) During the EC-ALD process the applied potential and the solution in cell must be changed for the deposition of each layer.



3) S^{2-} and Cd^{2+} UPD

Cyclic voltammograms (50mV/s) of Na_2S 1mM and $CdSO_4$ 1mM in ammonia buffer on Ag(111).



Francesco Carlà, Principal Beamline Scientist of I07

Rodeostat integration in EC-ALD system

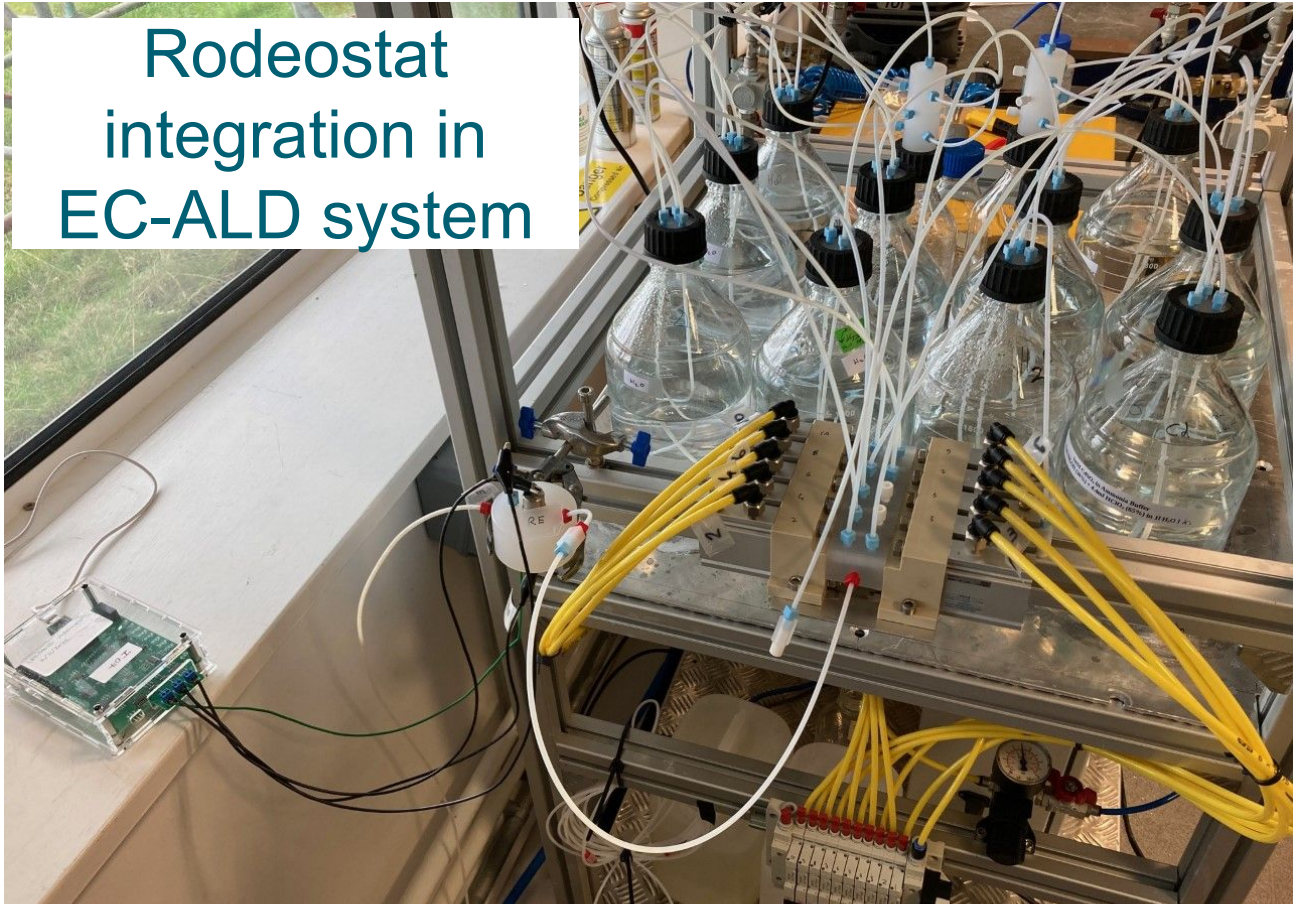
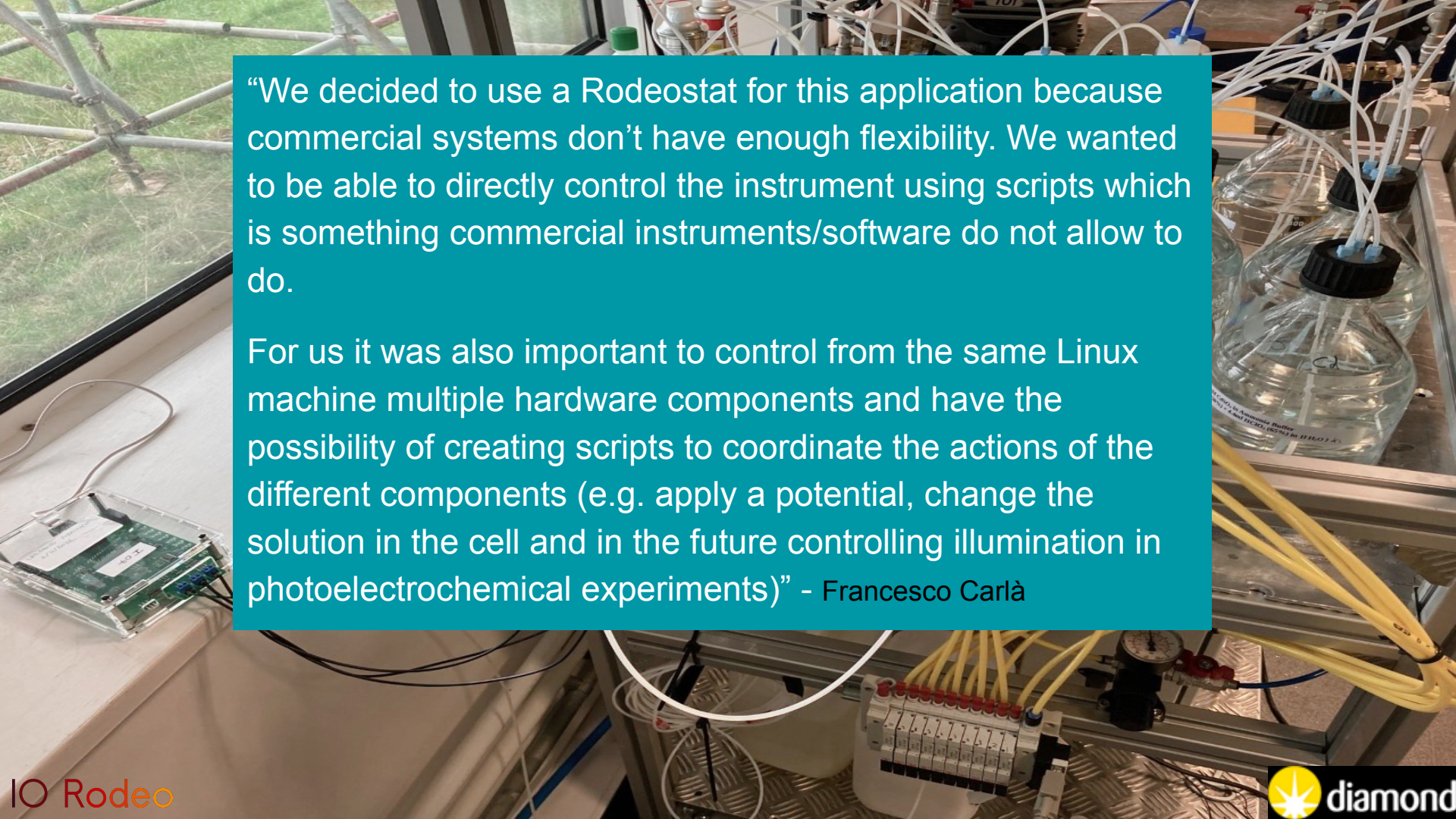


Image shows an electrochemical flow cell connected to the solution distribution system and the potentiostat. Several bottles containing different solutions are installed on the distribution system. Each bottle is pressurized with an inert gas and connected to a valve block, the valves can be opened and closed to flow the solution in the cell. **Image courtesy of Francesco Carlà, Principal Beamline Scientist of I07**

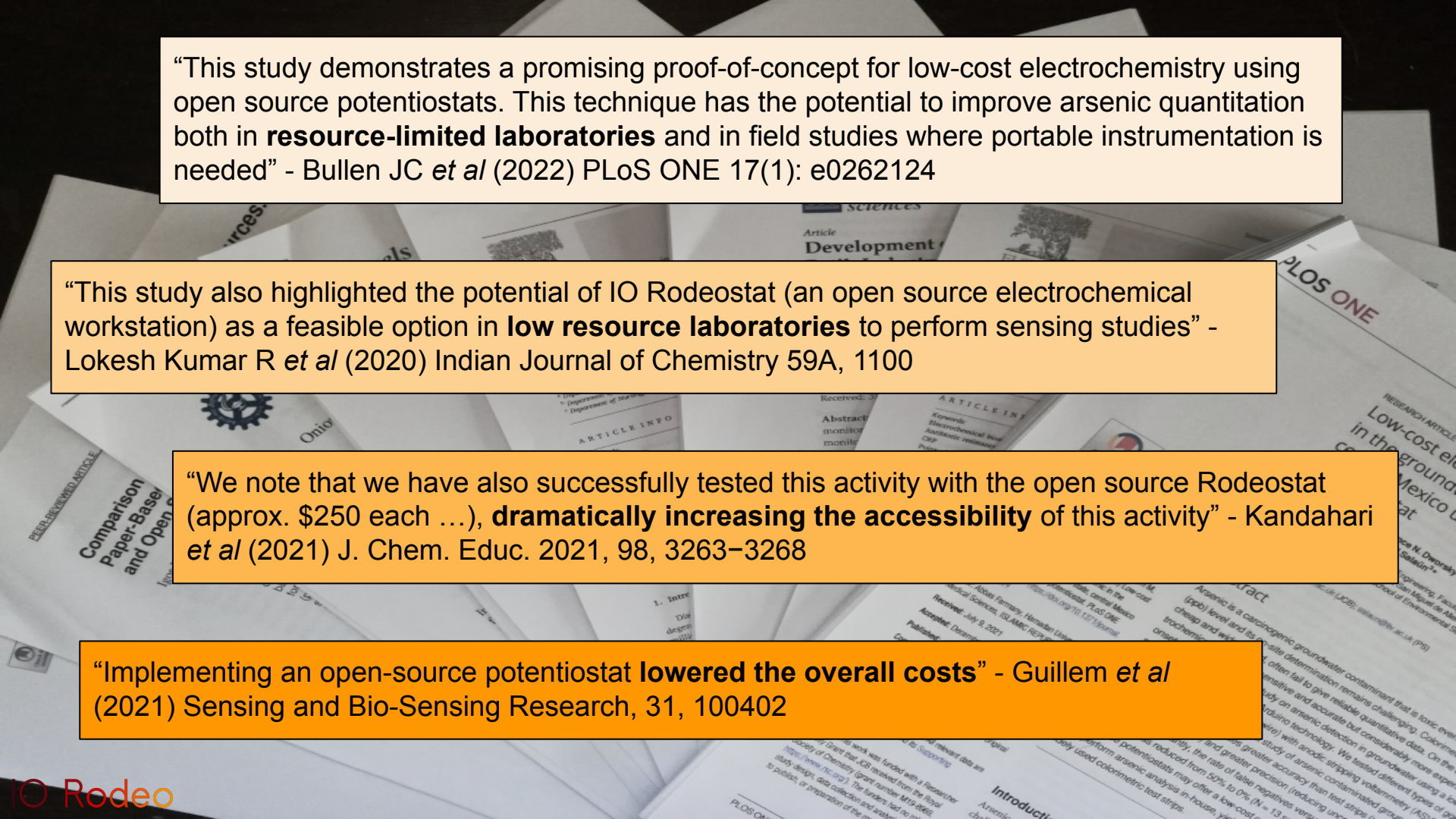
diamond



“We decided to use a Rodeostat for this application because commercial systems don’t have enough flexibility. We wanted to be able to directly control the instrument using scripts which is something commercial instruments/software do not allow to do.

For us it was also important to control from the same Linux machine multiple hardware components and have the possibility of creating scripts to coordinate the actions of the different components (e.g. apply a potential, change the solution in the cell and in the future controlling illumination in photoelectrochemical experiments)” - Francesco Carlà

IO Rodeo



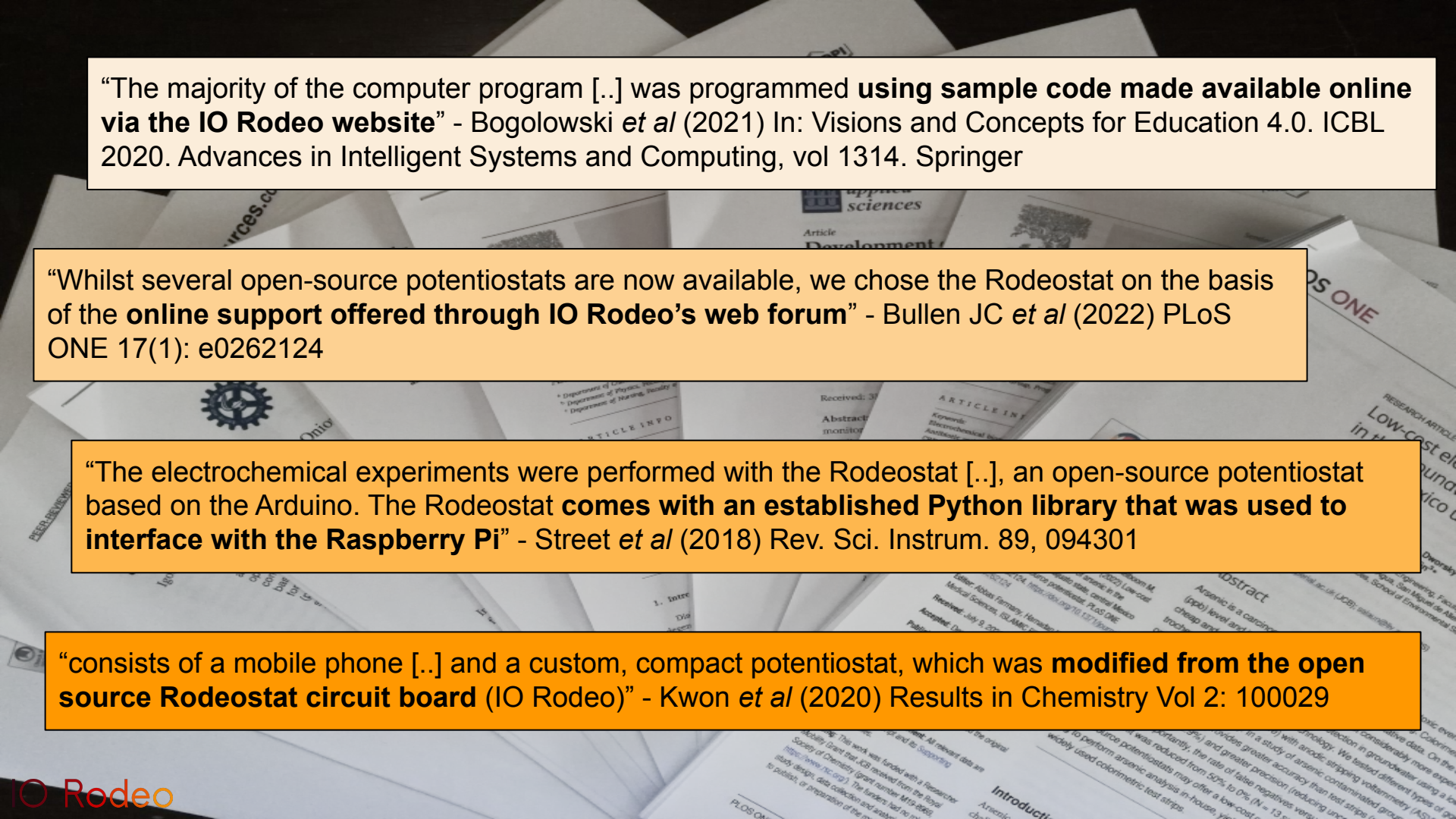
"This study demonstrates a promising proof-of-concept for low-cost electrochemistry using open source potentiostats. This technique has the potential to improve arsenic quantitation both in **resource-limited laboratories** and in field studies where portable instrumentation is needed" - Bullen JC *et al* (2022) PLoS ONE 17(1): e0262124

"This study also highlighted the potential of IO Rodeostat (an open source electrochemical workstation) as a feasible option in **low resource laboratories** to perform sensing studies" - Lokesh Kumar R *et al* (2020) Indian Journal of Chemistry 59A, 1100

"We note that we have also successfully tested this activity with the open source Rodeostat (approx. $250 each …), **dramatically increasing the accessibility** of this activity" - Kandahari *et al* (2021) J. Chem. Educ. 2021, 98, 3263−3268

"Implementing an open-source potentiostat **lowered the overall costs**" - Guillem *et al* (2021) Sensing and Bio-Sensing Research, 31, 100402

IO Rodeo



"The majority of the computer program [..] was programmed **using sample code made available online via the IO Rodeo website**" - Bogolowski *et al* (2021) In: Visions and Concepts for Education 4.0. ICBL 2020. Advances in Intelligent Systems and Computing, vol 1314. Springer

"Whilst several open-source potentiostats are now available, we chose the Rodeostat on the basis of the **online support offered through IO Rodeo's web forum**" - Bullen JC *et al* (2022) PLoS ONE 17(1): e0262124

"The electrochemical experiments were performed with the Rodeostat [..], an open-source potentiostat based on the Arduino. The Rodeostat **comes with an established Python library that was used to interface with the Raspberry Pi**" - Street *et al* (2018) Rev. Sci. Instrum. 89, 094301

"consists of a mobile phone [..] and a custom, compact potentiostat, which was **modified from the open source Rodeostat circuit board** (IO Rodeo)" - Kwon *et al* (2020) Results in Chemistry Vol 2: 100029

IO Rodeo

Some advantages of open source scientific hardware

- More easily incorporated into larger custom instruments
  - programmable, flexible
  - custom modifications to create new instruments
- Provides way to naturally include programming in science education
  - similar to what happens in practice
- Can dramatically increase accessibility to instrumentation
  - low cost, affordable
  - hands on learning

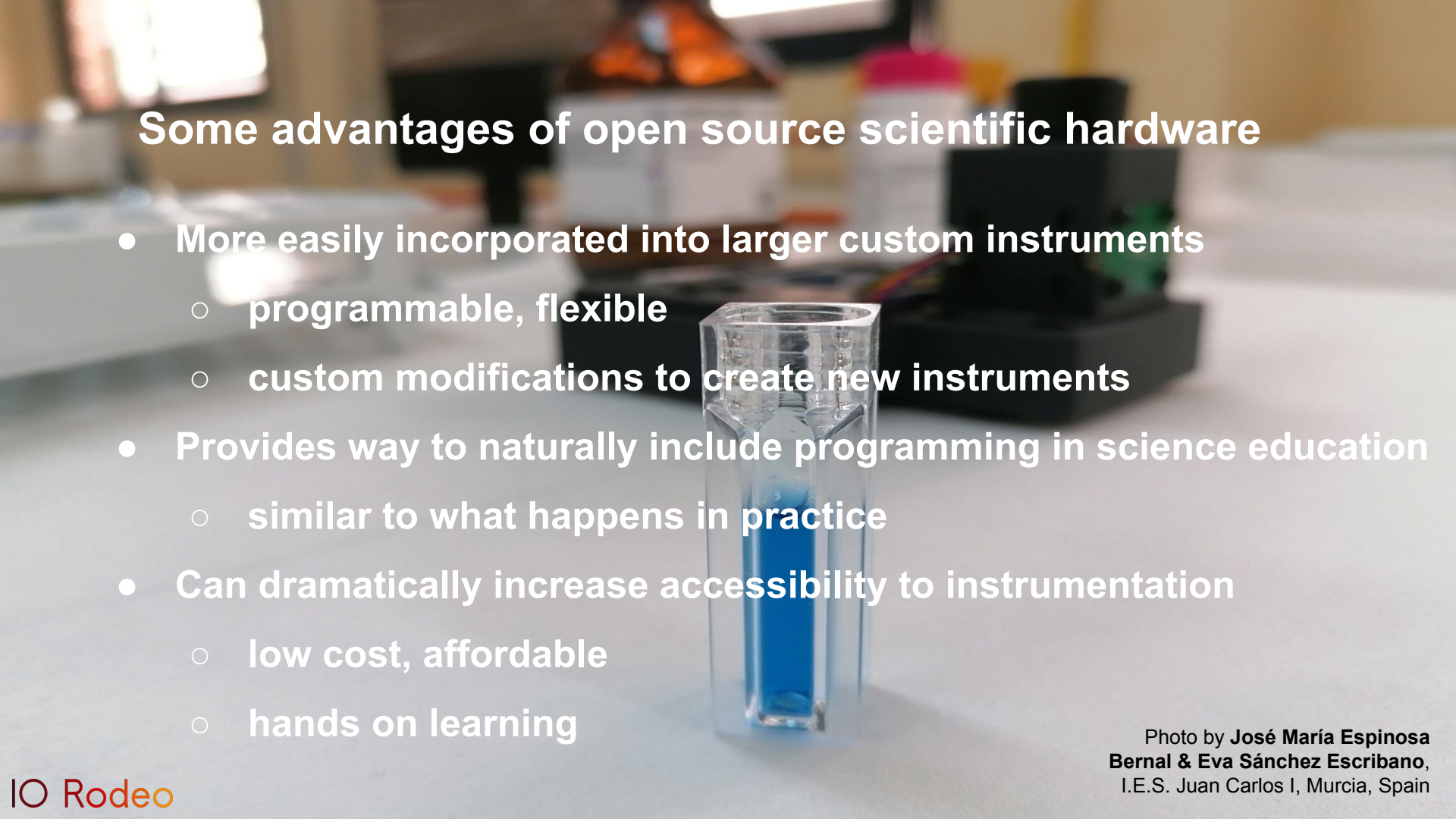
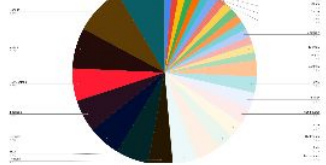


Photo by **José María Espinosa Bernal & Eva Sánchez Escribano**, I.E.S. Juan Carlos I, Murcia, Spain



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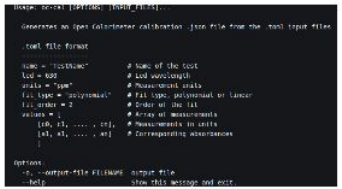

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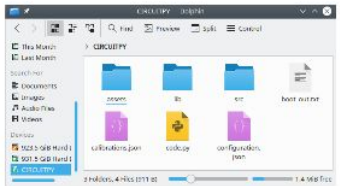

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