Device Architecture for Next Generation CdTe PV

Alexandra M. Huss[1], Anna Wojtowicz[1], Jennifer A. Drayton[1], James R. Sites[1], and Darius Kuciauskas[2]

[1]Colorado State University, Department of Physics, Fort Collins, CO, 80523, USA

[2]National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO 80401, USA

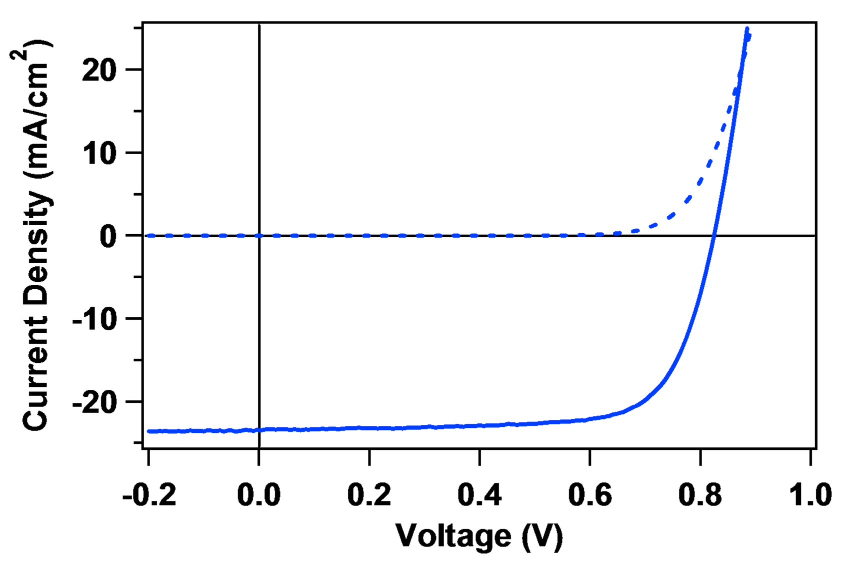
Project Goal

Achieve higher open-circuit voltages for CdTe cells without loss of current or fill-factor. The target is a 150 mV voltage increase that can be replicated in commercial modules.

Key Accomplishments

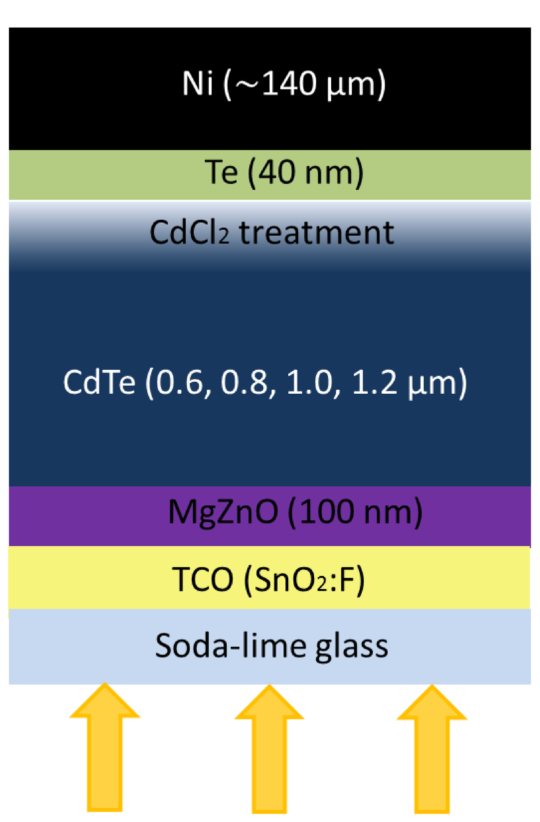
- **Good quality cells fabricated with systematic variation in CdTe thickness: 0.6, 0.8, 1.0, 1.2 µm**
- **Optimization of $CdCl_2$ passivation and Cu doping achieved**
- **Efficiency of cells with ~one-micron CdTe absorbers reached 14% with V_{OC} of 824 mV**
- **Cells show excellent crystal structure and continuous MgZnO and Te layers**
- **TRPL suggests low recombination at MgZnO interface, higher at Te interface**

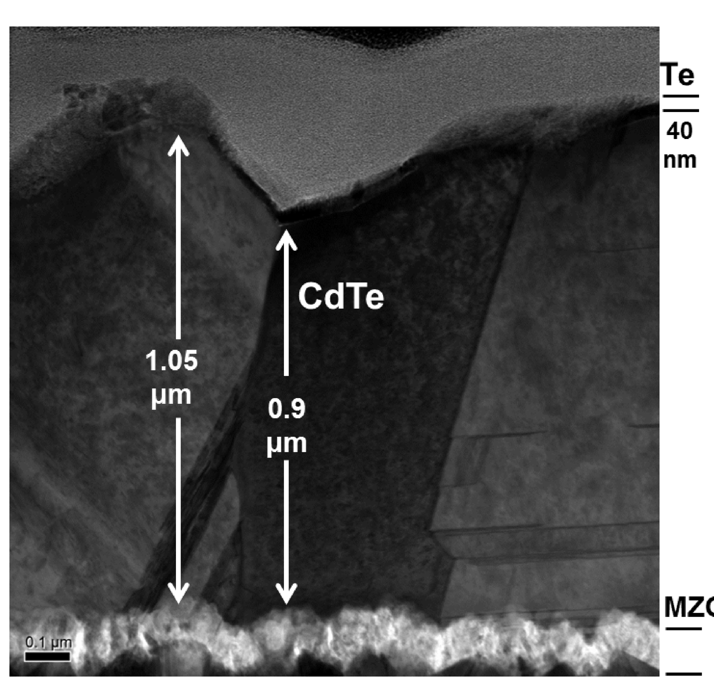
Record Thin-Absorber Device



- **Thickness ~ 1 µm**
- **V_{OC} = 0.824 V**
- **J_{SC} = 23.4 mA/cm²**
- **Fill Factor = 72.7%**
- **Efficiency = 14.0%**

Device Structure





Cross-sectional SEM shows

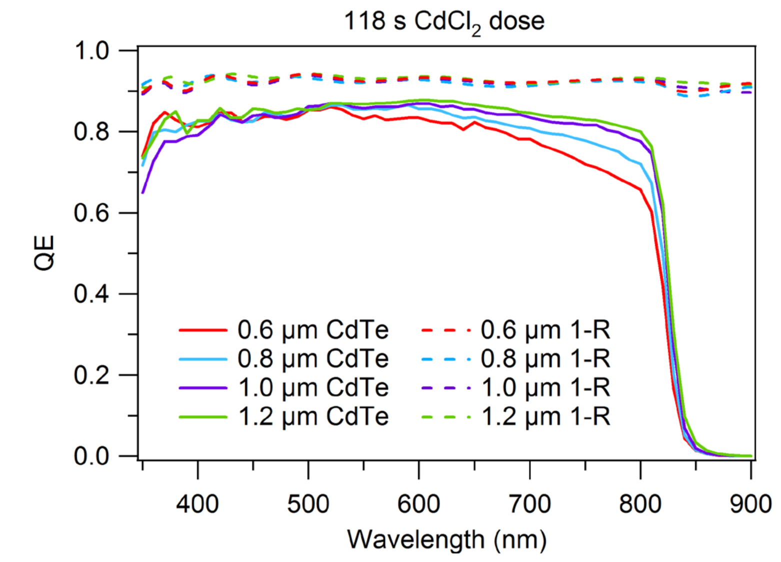
- **Large-grain CdTe**
- **Continuous MgZnO layers**

Device Characterization

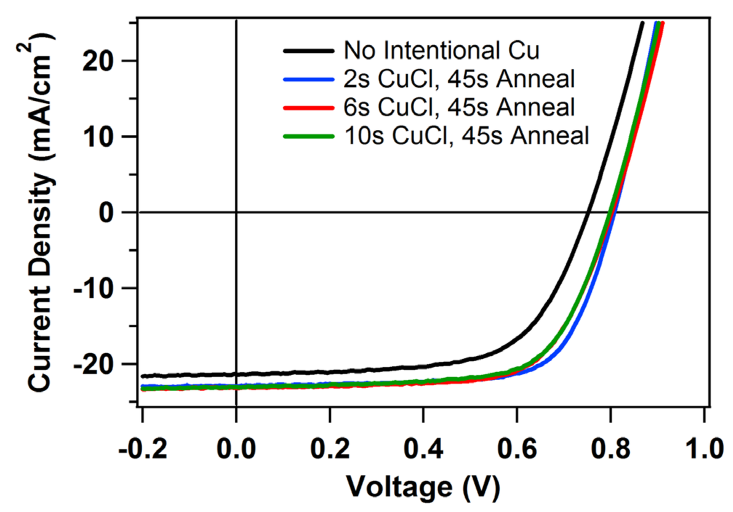
1. Optimization

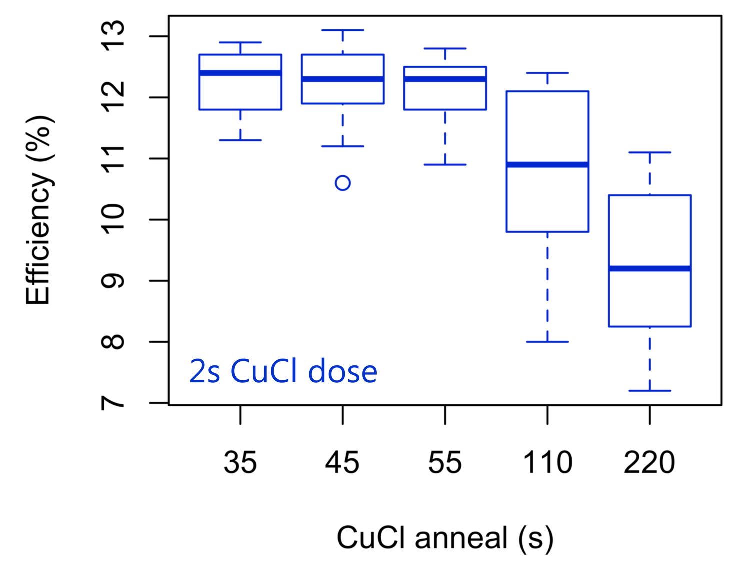
- **J-V parameters vs. $CdCl_2$ dose shows optimal dose time ≈120 seconds, independent of absorber thickness**
- **QE reveals thinner absorbers suffer more current loss at longer wavelengths due to incomplete absorption**

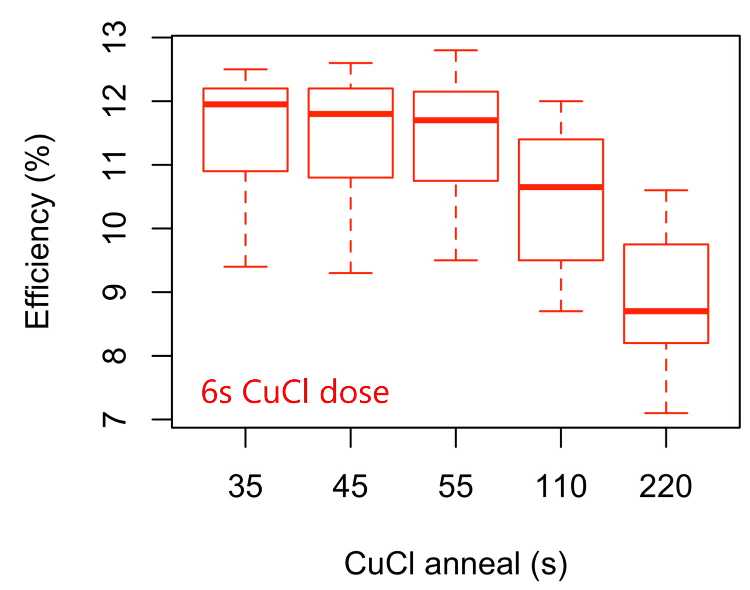
CdTe (µm)	J_{SC} (mA/cm²)	V_{OC} (mV)	FF (%)	η (%)
0.6	22.4	771	69.3	12.0
0.8	23.4	745	68.2	11.9
1.0	23.1	737	68.0	11.6
1.2	23.9	750	64.4	11.5

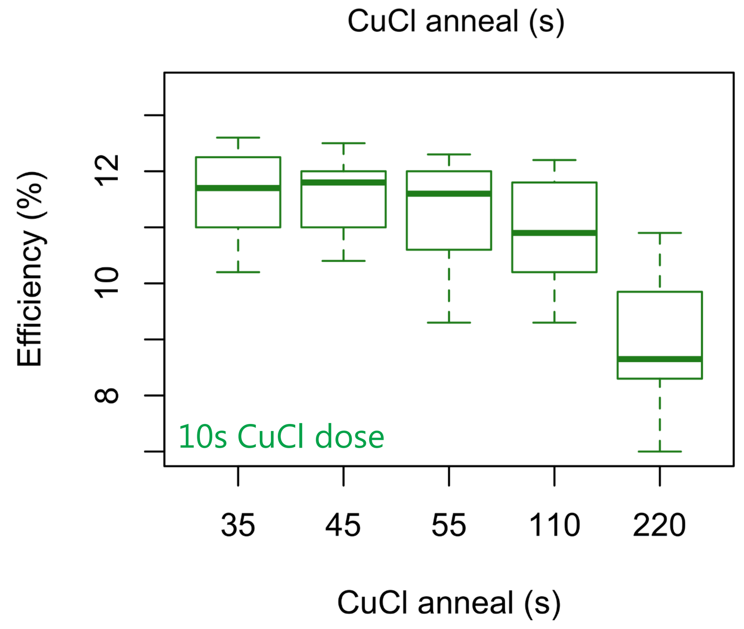


- **Efficiency as a function of CuCl doping and anneal time shows optimization of 2 second dose with ~50 second anneal**

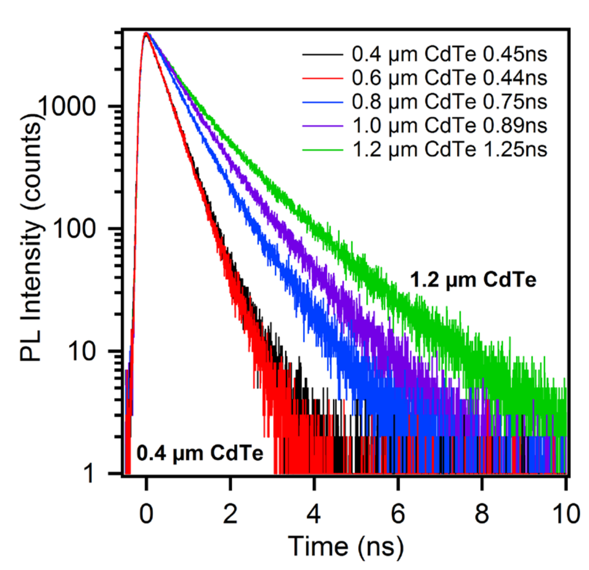


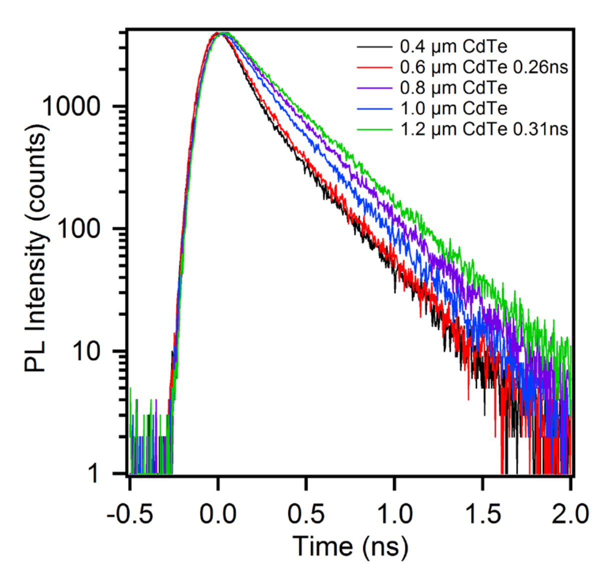






2. Time Resolved Photoluminescence (TRPL)

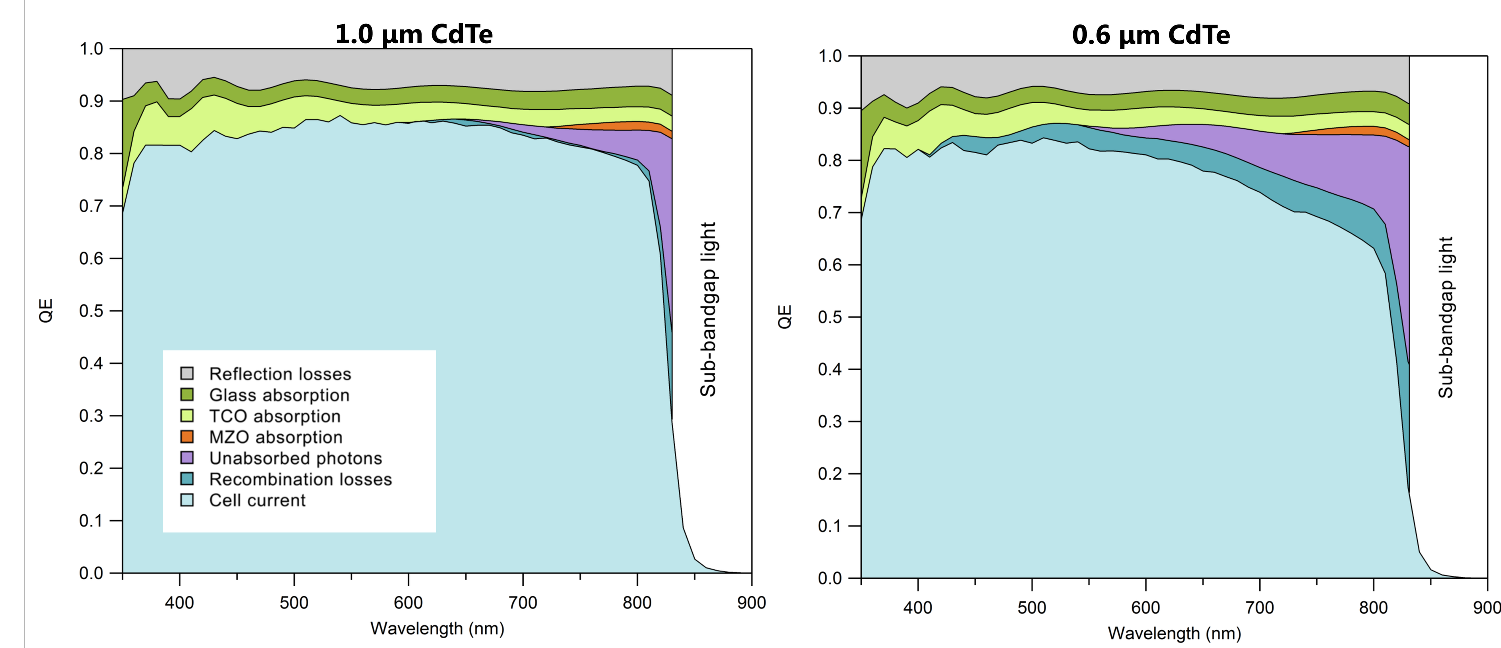




- **Single photon TRPL: lifetime increases with CdTe thickness**
- **Two photon TRPL (from Te side): lack of thickness dependence suggests back interface recombination dominates**

3. Loss Analysis

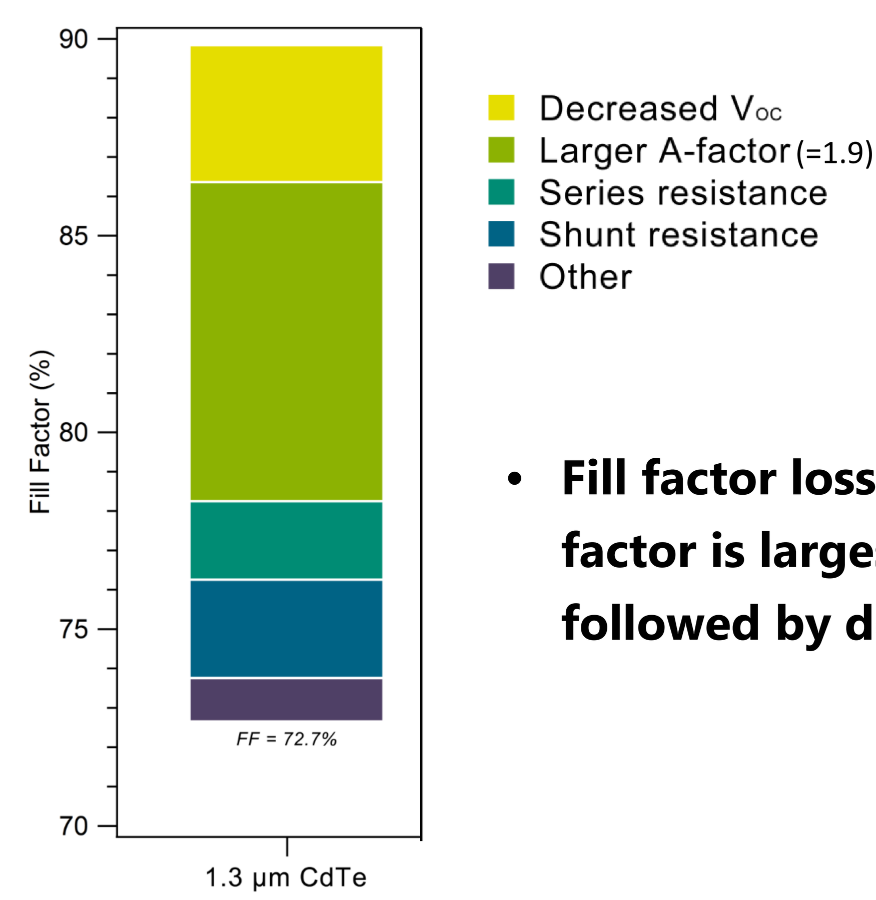
Current



Mechanism	1.0 µm Device Current Density (mA/cm²)	0.6 µm Device Current Density (mA/cm²)
Cell current	24.0	21.9
Reflection	2.1	2.1
Glass absorption	1.0	1.0
TCO absorption	1.1	1.1
MZO absorption	0.1	0.1
Unabsorbed photons	0.6	1.6
Recombination losses	0.1	1.2
Max current	28.9	28.9

- **QE losses show reflection is largest source of loss**
- **Losses due to unabsorbed photons and recombination increases for thinner absorber**

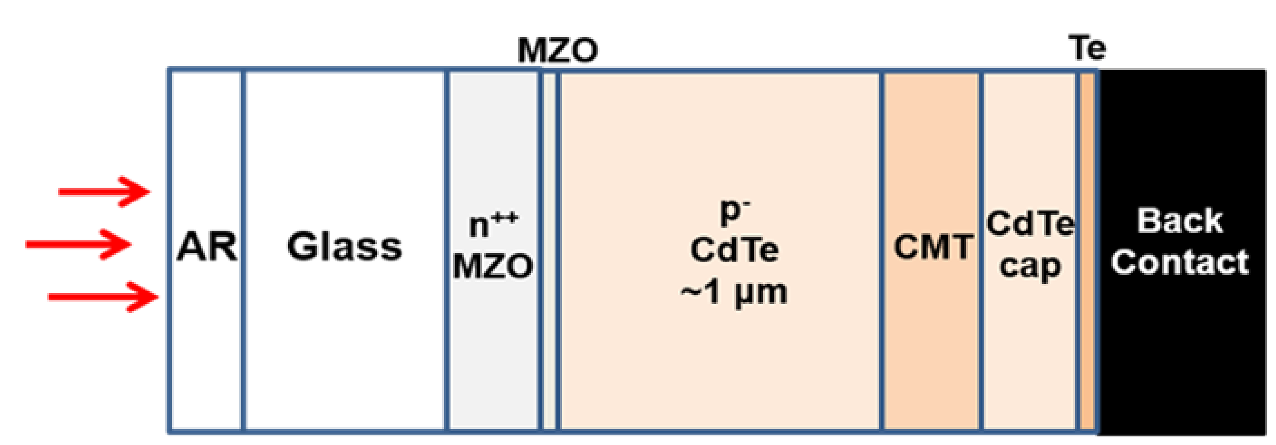
Fill Factor



- **Fill factor losses show a large A factor is largest source of loss followed by decreased V_{OC}**

Future of Project

- **Incorporation of electron reflector at back of device with addition of CdMgTe and CdTe cap layers**
- **Add Se to front of CdTe absorber**



Acknowledgments

The authors would like to thank Professor W.S. Sampath and Kevan Cameron for system use and support, Tushar Shimpi for SEM imaging, and Drew Swanson and Andrew Moore for helpful discussions. This work has been funded by the US DOE Photovoltaic Research and Development (PVRD) SunShot Initiative program DE-EE0007543.

Contact

Alexandra Huss
alexandra.huss@colostate.edu
Anna Wojtowicz
annawoj@colostate.edu
Jennifer Drayton
jennifer.drayton@colostate.edu
James Sites
james.sites@colostate.edu