Sputter-deposited Oxides for Interface Passivation of CdTe Photovoltaics

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Background and Motivation

Cadmium Telluride is the lowest cost PV technology and most widely deployed thin-film PV technology. Further efficiency gains require improved passivation of the bulk absorber material, grain boundaries, and interfaces.

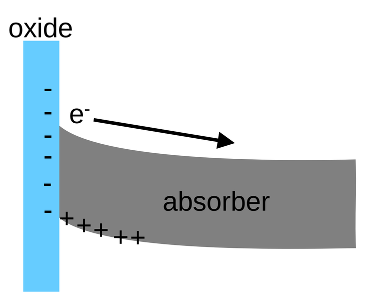
A highly resistive $Mg_xZn_{1-x}O$ (x = 0.23) window layer has previously been demonstrated to replace CdS as the CdTe front contact with 18.3% efficiency. Its bandgap of 3.7 eV nearly eliminates optical losses from the window layer. Oxide materials have the potential to further passivate the front and rear interface.

Interface Passivation Strategy

Oxides have shown interface passivation in c-SI, CIGS, CZTS, and other materials systems. Sputter deposition is favored by industry as a cost-effective deposition method.

Oxides were screened to identify the best passivation. Patterning of the oxide on the scale of the diffusion length is necessary to collect carriers through the insulator.

Aluminum oxide exhibits field-effect passivation, which has been shown for p-type c-Si, CIGS, and CZTS. Negative fixed charge repels minority carriers from the interface.

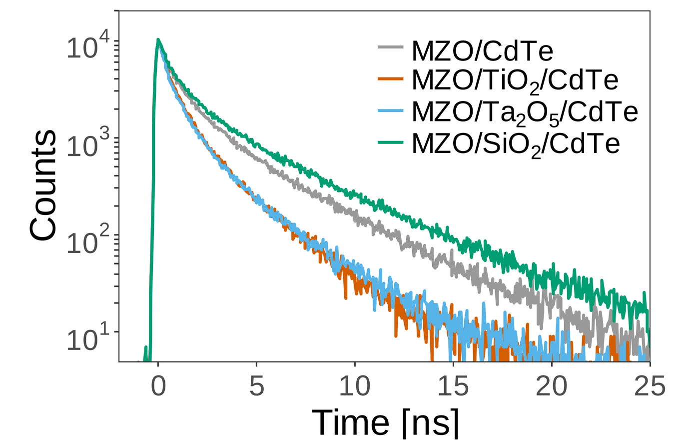


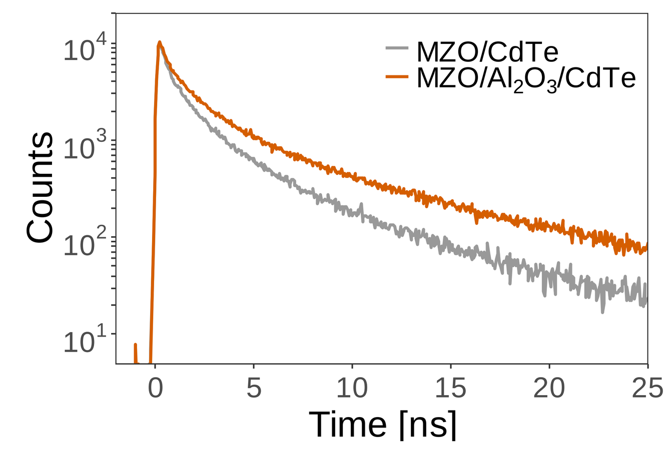
negative fixed charge repels minority carriers from interface

Oxide material screening (front passivation)

Candidate materials were chosen and deposited via RF magnetron sputter deposition (MSD) or ion beam sputter deposition (IBSD):

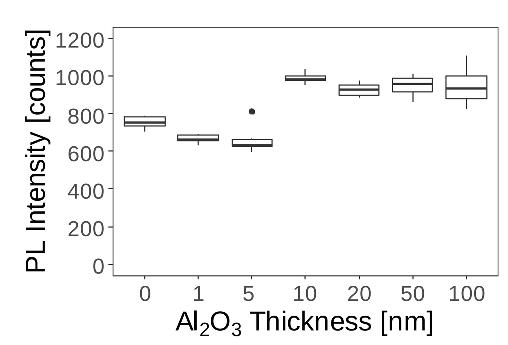
- MgO (MSD)
- $Mg_{0.35}Zn_{0.65}O$ (MSD)
- SiO_2 (IBSD)
- TiO_2 (IBSD)
- Ta_2O_5 (IBSD)
- Al_2O_3 (IBSD)

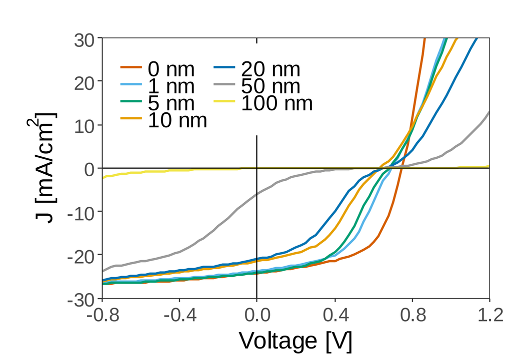




Time-resolved photoluminescence (TRPL) and photluminescence emission intensity (PL) were used to compare passivation due to oxide layers (full coverage) relative to baseline MZO/CdTe devices. MgO and $Mg_{0.35}Zn_{0.65}O$ had little effect compared to standard MZO. TiO_2 and Ta_2O_5 caused a decrease in lifetime, while SiO_2 and Al_2O_3 caused an increase. CdTe growth on SiO_2 was poor.

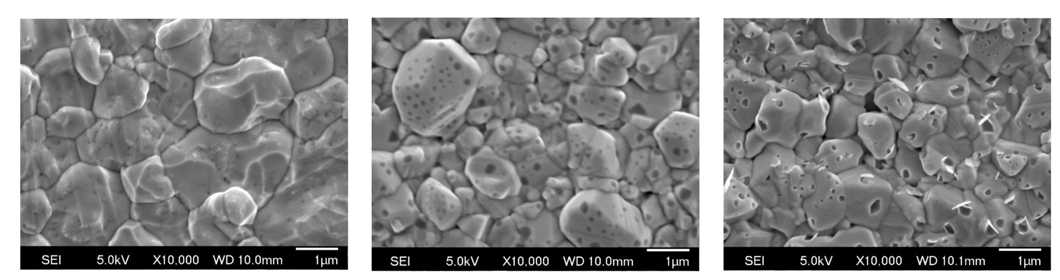
Front Al_2O_3 passivation





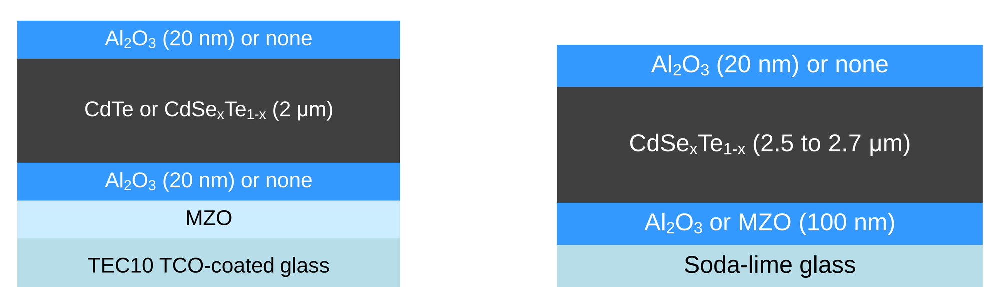
- Rear passivation has a stronger effect on lifetime
- MZO/CdSeTe/Al_2O_3 structures exhibit high lifetime
- Double heterostructures on glass exceed 500 ns

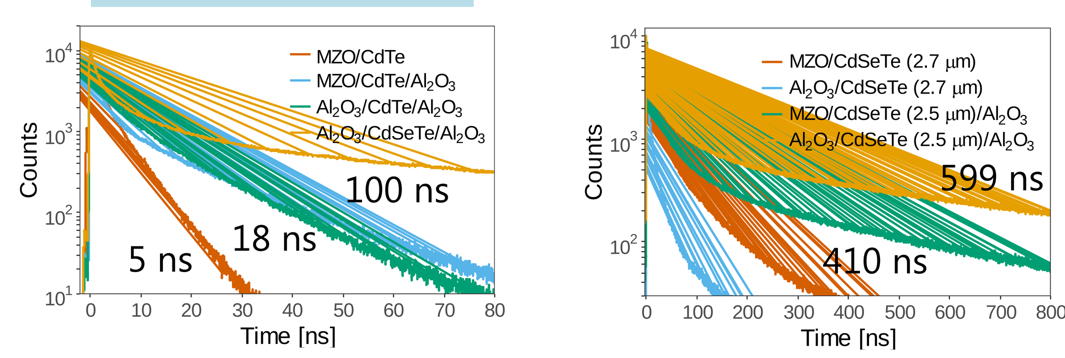
Rear Al_2O_3 passivation



CdTe/$CdCl_2$ CdTe/Al_2O_3/$CdCl_2$ CdTe/Al_2O_3/$CdCl_2$/Etch

$CdCl_2$ is performed after Al_2O_3 deposition

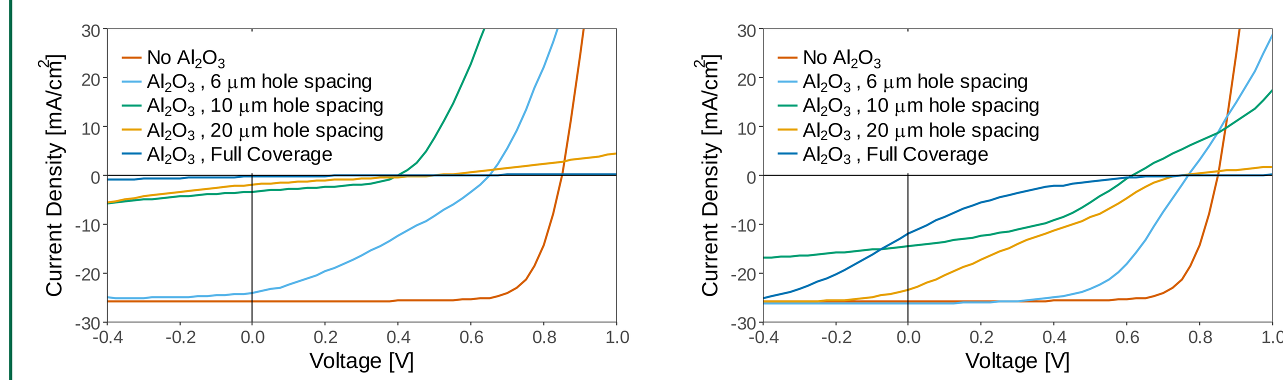




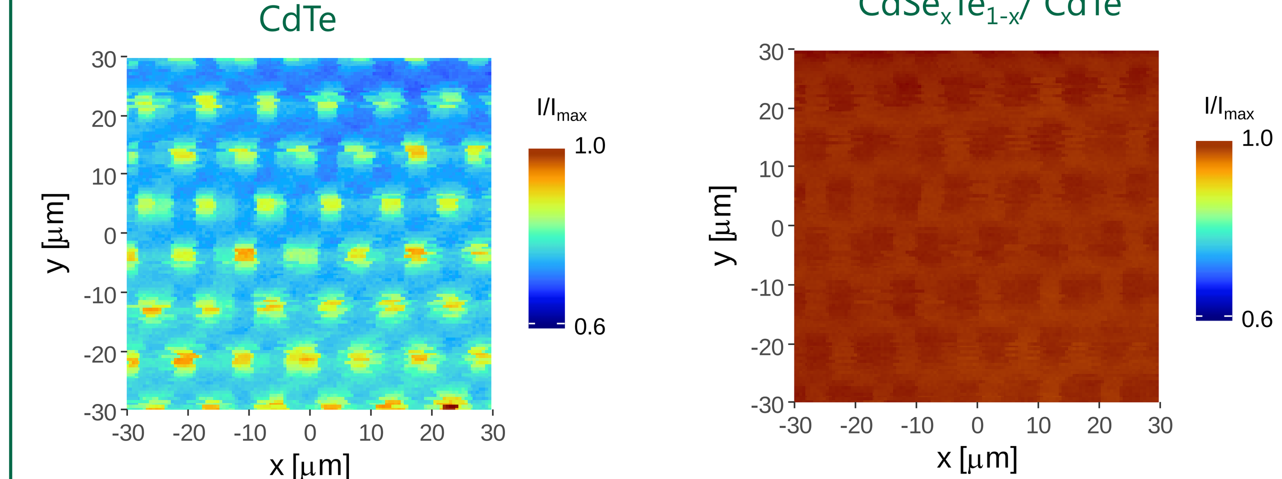
Lifetimes of 100 ns and 599 ns have been measured on TEC 10 and glass, respectively for front- and rear-passivation

Front-patterned Device Results

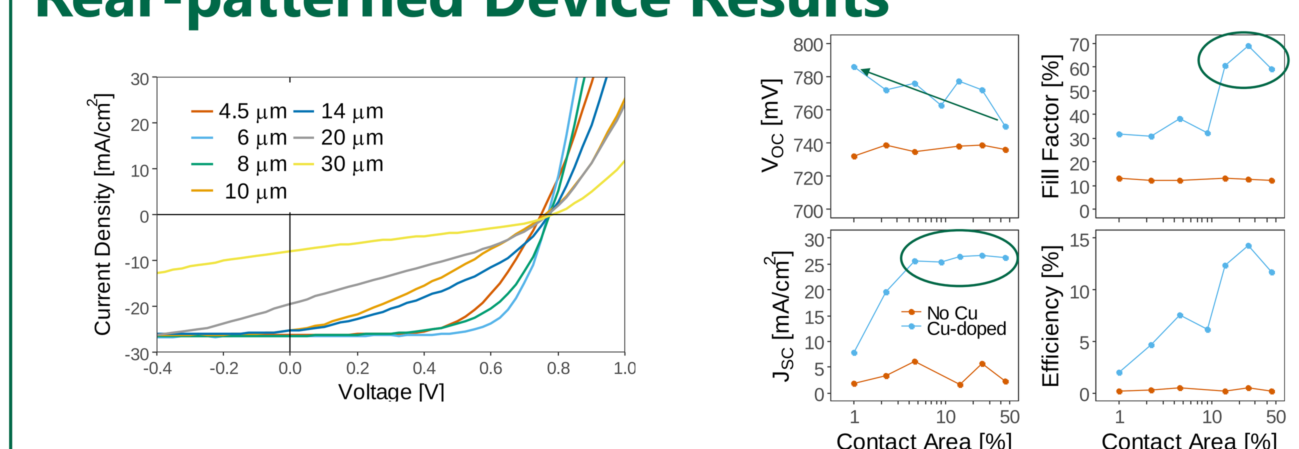
CdTe was deposited on patterned oxides with MZO point contacts. Here, devices with 20 nm Al_2O_3 are shown.



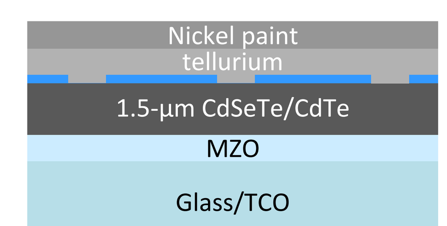
Laser beam induced current (LBIC) scans a focused laser (638 nm) across part of the cell to map photocurrent. In forward bias (0.4V), current collection is much more uniform for the device with a $CdSe_xTe_{1-x}$ graded absorber, attributed to its higher lifetime.



Rear-patterned Device Results

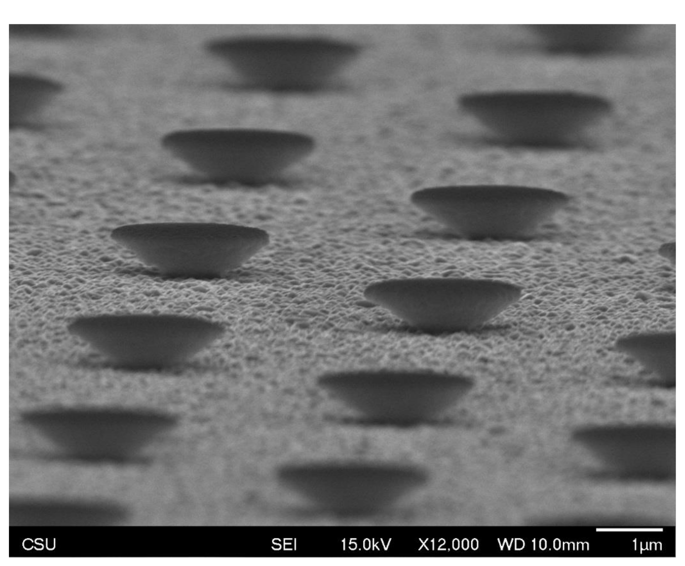


- Slight upward trend in V_{OC}
- Maintenance of FF and J_{SC} with significant Al_2O_3 coverage
- Improved contacting/doping needed

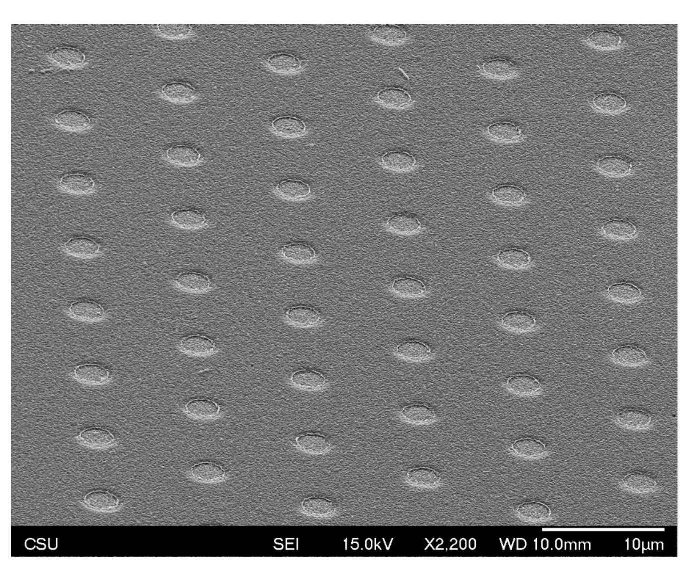


Micropatterning

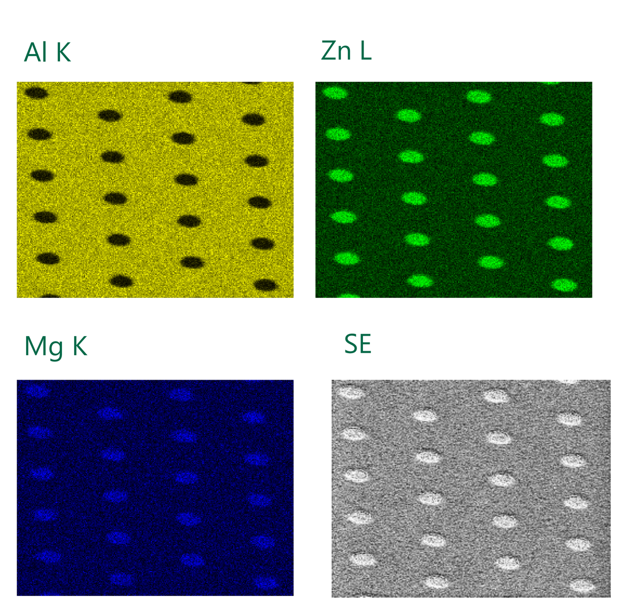
- Patterning of oxide layers was performed with photolithography
- A lift-off process was developed for materials that would be difficult to etch on top of MZO
- A an etching process was developed for Al_2O_3 using tetramethylammonium hydroxide, which can be used for front or rear passivation



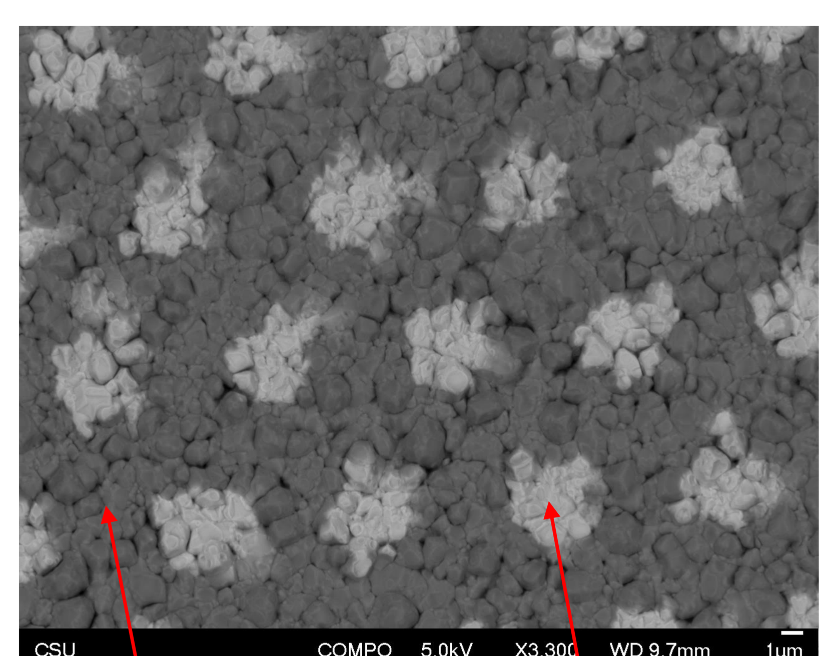
Photoresist on TEC10/MZO for lift-off

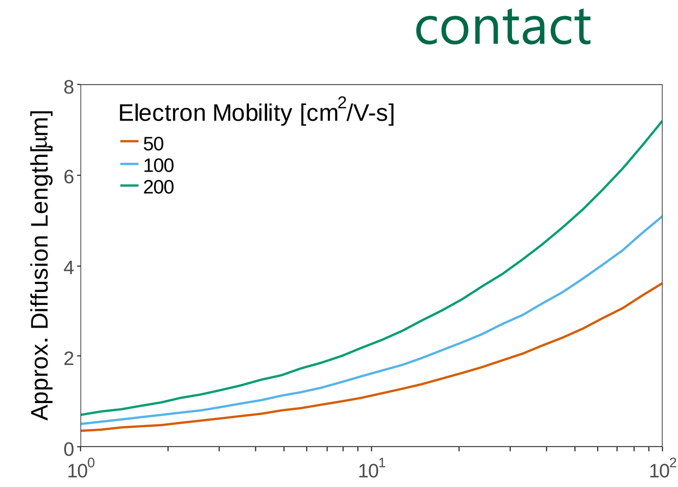


3-µm holes in Al_2O_3 patterned by lift-off



A backscattered electron image shows CdTe point contacts (light) surrounded by aluminum oxide (dark).





Conclusions

- Al_2O_3 passivates CdTe and CdSeTe interfaces
- CdSeTe/Al_2O_3 can produce lifetimes over 500 ns
- Front and rear patterning can be performed with 3-µm point size
- Improved doping and contact resistance are needed for high efficiency

Acknowledgments

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