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 Mg₂Zn₁₋ₓO (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.

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
- An etching process was developed for Al₂O₃ using tetramethylammonium hydroxide, which can be used for front or rear passivation

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)
- SiO₂ (IBSD)
- TiO₂ (IBSD)
- Al₂O₃ (IBSD)
- Mg₃Zn₁₋ₓO (MSD)
- Ta₂O₅ (IBSD)
- Mg₃Zn₁₋ₓO (IBSD)

Time-resolved photoluminescence (TRPL) and photoluminescence emission intensity (PL) were used to compare passivation due to oxide layers (full coverage) relative to baseline MZO/CdTe devices. MgO and Mg₃Zn₁₋ₓO had little effect compared to standard MZO TiO₂ and Ta₂O₅, causing a decrease in lifetime, while SiO₂ and Al₂O₃ caused an increase. CdTe growth on SiO₂ was poor.

Front Al₂O₃ passivation
- Rear passivation has a stronger effect on lifetime
- MZO/CdSeTe/Al₂O₃ structures exhibit high lifetime
- Double heterostructures on glass exceed 500 ns

Rear Al₂O₃ passivation
Lifetime 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 Al₂O₃ are shown.

Conclusions
- Al₂O₃ passivates CdTe and CdSeTe interfaces
- CdSeTe/Al₂O₃ 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

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