

Non-Pyrophoric Al Precursor for the ALD of Al₂O₃ and Al-Doped ZnO

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Thin oxide films containing Al are of interest for photovoltaic applications. The dielectric Al₂O₃ provides excellent surface passivation of crystalline silicon (c-Si) solar cells by lowering the surface recombination velocity of charge carriers within the c-Si.¹ Al is also an important component in transparent conducting oxide (TCO) materials, such as ZnO:Al (AZO), which are required for several solar cell types as an electrode.² The AZO's resistivity can be tuned by varying the Al concentration. Atomic layer deposition (ALD) is an excellent method for the deposition of the aforementioned films as it gives good uniformity and conformality, and allows for accurate doping control. Currently, trimethylaluminium (TMA) is the most commonly-used Al precursor, although it is pyrophoric. A non-pyrophoric alternative is dimethylaluminium isopropoxide (DMAI),³ which is safer for high-volume manufacturing. We present here a comparison of TMA and DMAI as Al precursors for c-Si surface passivation and ZnO doping by plasma and thermal ALD in the same reactor.

To investigate the surface passivation, 30 nm thick Al₂O₃ films were deposited using DMAI onto HF-dipped *n*- and *p*-type floatzone c-Si wafers and the effective carrier lifetimes were measured. The maximum surface recombination velocities ($S_{eff,max}$) were then calculated (Fig. 1) for as-deposited films and films annealed at 400 and 800 °C, the latter designed to mimic the metal contact firing process in solar cell manufacturing. Thermal ALD gave $S_{eff,max}$ values in the order of 20 (*n*-type Si) and 100 cm/s (*p*-type Si), which were not affected significantly by annealing or firing. The as-deposited $S_{eff,max}$ values for plasma ALD were much higher, but were dramatically improved with annealing.

TMA and DMAI were also used for the deposition of nominally 40 nm thick AZO films onto glass using thermal and plasma ALD with diethylzinc (DEZ) as the Zn precursor. The nucleation and growth of Al₂O₃ using both Al precursors were tested on a ZnO substrate. The nominal Al content was calculated from the ZnO:Al₂O₃ cycle ratio. The film resistivities (Fig. 2) were measured within 1 h after deposition using the four-point probe method. The films deposited using plasma ALD had higher resistivities (1-100 Ω.cm) than those deposited using thermal ALD (0.01-1 Ω.cm), the latter being expected of 40 nm thick AZO films.

Using these results, we will discuss the potential of DMAI as a viable alternative to TMA for such photovoltaic applications as c-Si surface passivation and TCO deposition.

1. G. Dingemans *et al.*, *Phys. Status Solidi RRL*, **4**, 10 (2010).
2. A. Janotti and C. G. Van de Walle, *Rep. Prog. Phys.*, **72**, 126501 (2009).
3. S. E. Potts *et al.*, *J. Vac. Sci. Technol. A*, **30**, 021505 (2012).

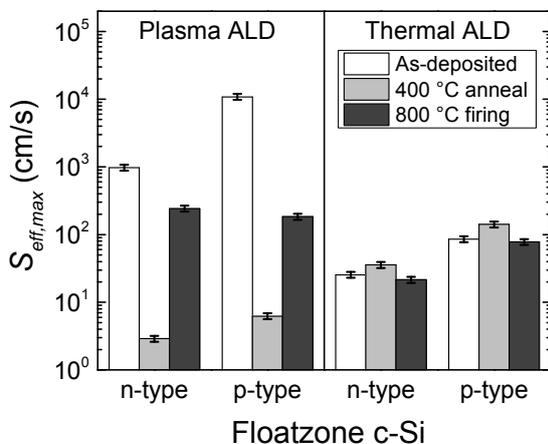


Fig. 1. Surface recombination velocities (injection level $5 \times 10^{14} \text{ cm}^{-3}$) of floatzone c-Si coated with 30 nm Al₂O₃ from DMAI. Measurements were taken for as-deposited films, films annealed at 400 °C and films “fired” at 800 °C.

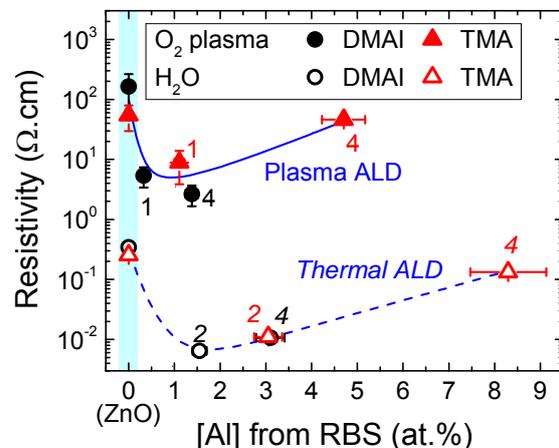


Fig. 2. Resistivities of 40 nm thick AZO films on glass deposited by plasma and thermal ALD using TMA and DMAI as the Al source. The data labels represent the nominal Al concentration. Lines serve as a guide to the eye.