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NATIONAL RENEWABLE ENERGY LABORATORY

Examination of Na-Doped Mo Sputtering for CIGS Devices

Cooperative Research and Development Final Report

CRADA Number: CRD-10-375

NREL Technical Contact: Ingrid Repins

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Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI.A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA number: CRD-10-375

CRADA Title: Examination of Na-Doped Mo Sputtering for CIGS Devices

Parties to the Agreement: Climax Molybdenum

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	**NREL** Shared Resources
Year 1	$ 00.00
Year 2	$ 00.00
Year 3	$ 00.00
TOTALS	$ 00.00

Abstract of CRADA work:

Na is an important ingredient in $Cu(In,Ga)(Se,S)_2$ (CIGS) photovoltaic devices, due to its ability to increase carrier density and passivate surfaces, grain boundaries, and Se vacancies. In the highest efficiency devices, Na is supplied to the growing CIGS film by diffusion through the Mo back contact from the soda-lime glass substrate. This arrangement is problematic in that the Na content of the film is only indirectly controlled: deposition times, deposition temperatures, Mo morphology, and glass composition are coupled with the Na diffusion. Results in the literature show that the Mo, not the CIGS, is the primary barrier to Na diffusion. Alternatively, using a Na-free substrate or diffusion barrier, Na may be introduced by a NaF precursor deposited on top of the Mo. However, this forces a trade-off between carrier density and adhesion. If the NaF is not entirely consumed, the CIGS layer peels away from the Mo, encouraging the use of less NaF even though the best device properties tend to result from the thickest possible NaF layers. Furthermore, although early studies show that gross control of Na is sufficient to produce 12-14% small devices, the industry has reached this level and is ready to progress to higher performance. The sensitivity of NREL device efficiency (15 to 20%) to Mo morphology suggests that fine control of Na content is necessary for very high performance. This work has investigated the use of Na doped Mo ("MONA") sputtering targets for use in preparing CIGS devices. The Mo:Na material is doped to about 3% Na by weight, implying that a 40 nm layer on top of the standard Mo contact

contains sufficient Na to dope a 2.5 μm CIGS film. The ability to control Na doping independent of both CIGS processing conditions and adhesion is an important gain for industry and research. Manufacturers gain a route to increased manufacturability and performance, while NREL researchers gain a tightened performance distribution of devices and increased process flexibility. Our immediate partner in this work, the Climax Molybdenum Technology Center, gains validation of their product.

Summary of Research Results:

High-efficiency CIGS solar cells were fabricated using Na-doped Mo as a Na source. Film analysis revealed the positive result that CIGS grown on 400 nm Mo:Na had higher Na incorporation than CIGS grown on the industry standard NaF-coated substrates. Devices produced on the Mo:Na had higher open-circuit voltage, fill factor, and efficiency than those on NaF. A champion device with 16.6% efficiency was fabricated on 160 nm of Mo:Na with a 500 A Mo cap layer and an anti-reflective coating. Film analysis from the thickest Mo:Na layers shows that Na content in the CIGS can be made to exceed even that in high-efficiency devices on SLG. However, additional effort is needed to obtain acceptable adhesion for these thicker Mo:Na layers. Based on these data, Mo:Na may provide a manufacturing solution for controllable Na incorporation in CIGS solar cells.

Subject Inventions listing:

None.

Report Date: 12/13/11 Responsible Technical Contact at Alliance/NREL: Ingrid Repins

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