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AMORPHOUS SILICON IN PHOTOTHERMAL CONVERSION*

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Abstract.-Efficient conversion of solar energy into heat requires a spectrally selective surface to function as a one-way valve between the incident radiation and heat transfer system. The tandem action of a solar absorber overlying an infrared reflector gives this action, provided the absorber is transparent in the thermal infrared /1/. Our group has fabricated such tandem stacks, durable at high temperatures, by depositing both absorber and reflector layers by Chemical Vapor Deposition (CVD), a method of economic promise for large-scale production /2, 3/.

Although the initial work used polycrystalline silicon as the solar absorber, it was realized that amorphous silicon could raise the solar absorptance of the CVD tandem stacks /4/. However, there existed a major obstacle to its use: amorphous silicon deposited by the two most widely used methods of physical vapor deposition, evaporation and sputtering, crystallized near 550°C /5/. This temperature is too low for photothermal energy converter operation. It is also so low that the pyrolytic decomposition of silane, the basic reaction for producing silicon CVD, proceeds at an infinitesimal rate.

In an attempt to pass through the amorphous-to-crystalline transition temperature of 550°C without reducing the deposition rate too drastically, we learned that silicon fabricated by CVD is amorphous for substrate temperatures, \( T_S \), of up to 670°C. The improved thermal stability of the amorphous phase may be credited to the presence of hydrogen, incorporated into the film in amounts to less than 1 at. % depending upon \( T_S \), due to the incomplete breakup of the silane molecule /6/.

Although far below the hydrogen content characteristic for material deposited in an RF flow discharge, this fraction of 1 at. % of hydrogen effectively terminates dangling bonds. Electron spin resonance indicates spin densities in the order of \( 10^{19} \text{cm}^{-1} \) in the CVD material /7/.

The considerable thermal stability of CVD amorphous silicon promises satisfactory operation of the absorber over extended periods of time at 450°C. Specific density, absorption coefficient, and refractive index were determined, the optical data confirming the superiority of amorphous over polycrystalline silicon as a solar absorber. Anneal at temperatures below the crystallization temperature \( T_c \) of 670°C proved that CVD amorphous silicon, unlike material deposited by other methods, is anneal-stable /8/.

The hypothesis that the retardation of the crystallization is caused by the presence of hydrogen stimulated a search for an even better stabilizer. Among the various elements introduced from the vapor phase into the growing film the most promise is shown by car-

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Codeposition of 18 at. % carbon from acetylene gives a material that retains the solar absorptance of the non-intentionally doped amorphous silicon, but retards crystallization to 950°C. Extrapolation on the basis of the crystallization kinetics predicts structural stability of this solar absorber over hundreds of years at 700°C operating temperature.

References


