depends on proximity to the Sun, which is unlikely to favour atypical stars, and the derived masses extend over a comfortably large range. On the other hand, perhaps it is possible to reach the white-dwarf state without passing through the planetary-nebular phase; in that case not every white dwarf has been a planetary nucleus. The nucleus of planetary nebula A63 has been found to be a member of an eclipsing binary system, leading to an estimated mass of 0.9 $M_\odot$ (ref. 7). The planetary nucleus in A46, also a binary star, has a mass perhaps as large as 1.1 $M_\odot$ (ref. 8). But these two objects may not represent firm evidence for high mass in planetary nuclei because in each of the binaries, only the ratio of stellar masses is well determined[9].

Three very luminous planetary nuclei in the Magellanic Clouds, whose distances and luminosities should be beyond doubt, have masses of 0.9–1.2 $M_\odot$ derived by comparison of the stellar parameters with evolutionary tracks in the log L–log T plane[10]. These masses cannot be much on the high side because the stellar luminosities would exceed the Eddington luminosities (at which radiation pressure disperses a star) for stars with masses smaller than those derived. Considering the white dwarf Sirius B with astrometrically determined mass of 0.94 $M_\odot$ the planetary nuclei in eclipsing binary systems and the planetary nuclei in the Clouds, one suspects that there may be more high-mass planetary nuclei than the Schoenberner and Weidemann scheme can comfortably confront, despite the uncertainties mentioned above. Are the three Magellanic Cloud planetary nuclei atypical? Recent IUE observations of several additional nebulae in the Clouds may help to say. In any case the measurement of luminosities and temperatures for a substantial sample of planetary nuclei in the Magellanic Clouds, a project planned for the faint object spectrograph on the Space Telescope[11], should put the matter beyond doubt. □

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Chemistry

A novel solar cell

from Nathan S. Lewis

SEMICONDUCTOR-LIQUID junctions offer a possible alternative to conventional solid state photovoltaic solar energy conversion devices. Unfortunately, few of the semiconductor–liquid solar cell systems explored to date simultaneously meet the necessary criteria of excellent stability and high efficiency; thus, the search for novel electrode materials is proceeding with fervour. In the last issue of *Nature,* Menezes, Lewerenz, and Bachmann (*Nature* **305,** 615; 1983) reported studies of a new semiconductor–liquid junction solar cell that demonstrates excellent stability in an atmospheric environment, and simultaneously displays solar-to-electrical energy conversion efficiencies of 9.5 per cent.

The basic operating principles of semiconductor–liquid junction solar cells resemble those of solid state cells (see *News and Views* **733,** 687, 1982). When a semiconductor is immersed in a liquid electrolyte with a suitable oxidation-reduction species present, a junction is spontaneously formed. This junction allows efficient photovoltaic action to occur, and provides a mechanism to harness incident photon energy into useful electrical work.

In addition to accomplishing the desired chemical reactions, the photogenerated carriers can also undergo side reactions which lead to decomposition or passivation of the semiconductor itself. This is a general phenomenon for photoanodes in aqueous solution and severely limits the lifetime of semiconductors–liquid junction devices. Finding a way of minimizing decomposition reactions while maintaining high photovoltaic efficiencies is crucial to the development of useful interfaces. Approaches include the use of nonaqueous solvents to minimize decomposition, and the addition of reagents to aqueous electrolytes which might compete favourably with the decomposition pathways.

Menezes and collegues find that a *n*-$CuInSe_2$ anode immersed in an aqueous iodide solution exhibits negligible photocorrosion processes and 9.5 per solar efficiency. Significantly, the iodide–iodine solution does not have to be stringently sealed from the atmosphere in order to maintain efficient operation. The authors also point out that a simple chemical reaction of the interface can be used to promote cell stability. In the case of the $CuInSe_2$ device, *in situ* film formation induced by the addition of Cu ions to the electrolyte solution yields anodes which are stable for periods of over five months. The system thus compares favourably with the best stability observed in any semiconductor–liquid junction, and signals that it may indeed be possible to find specific semiconductor–liquid combinations that will be durable over the long periods necessary for successful terrestrial photovoltaic operation.

An important point raised by Menezes and colleagues is that the $CuInSe_2$ semiconductor material used in their cell might be advantageously employed in a thin film electrode configuration. This suggestion is made because the absorption edge of the $CuInSe_2$ is of the direct bandgap type. The optical absorption coefficient of the semiconductor at a particular wavelength of light determines the profile of carrier creation, with stronger absorption implying carrier creation closer to the junction. In general, there are two distinct sources of photovoltaic action: diffusion currents and drift currents. Drift currents arise when the photogenerated carriers are created within the region of the junction field, while diffusion currents result from deeply penetrating photons which create carriers in the bulk of the semiconductor. Since the diffusion currents are substantially more sensitive to impurities in the crystal than are the drift currents, the strong optical absorption by the $CuInSe_2$ allows use of thinner, and less perfect samples than would be required of semiconductors such as silicon. This advantage, if exploited, could enable fabrication of photovoltaic cells in a thin film assembly without substantial loss of efficiency. However, the authors have so far restricted their investigations to the behaviour of the more expensive single crystal $CuInSe_2$, and a judgement on the behavior of polycrystalline materials must await further study.

At present, the relative merits of semiconductor–liquid junction cells versus conventional space cells is a matter of debate; indeed, there is controversy over estimates of the economic feasibility of any large scale terrestrial solar device. With regard to an actual energy conversion application, it is clear that the technology of semiconductor–liquid junction cells substantially lags behind that of solid state systems. It is equally clear, however, that progress in the area is rapid, and that the basic science of the semiconductor–liquid interface poses a challenging scientific problem. Investigations which advance our understanding of the chemistry at any semiconductor junction, including liquid interfaces with $CuInSe_2$, serve to provide a valuable piece of the scientific puzzle involved in the development of alternative energy sources. □

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