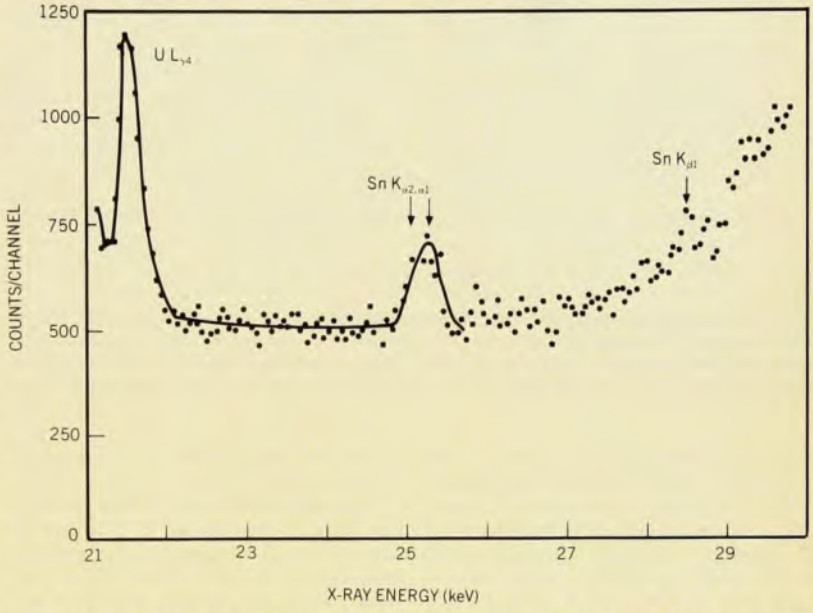
search & discovery

Evidence for superheavies in mica looks weaker

Last June when evidence for the presence in several mica samples of element 126 and possibly numbers 116, 124 and 127 was reported, great excitement was generated (PHYSICS TODAY, August 1976, page 17). The experiment, by a collaboration from Oak Ridge, University of California at Davis and Florida State University, had been done[1] by bombarding the sample with protons and looking for characteristic x rays from elements between $Z = 105$ and $Z = 134$. Now a variety of follow-up experiments have been done by members of the original team and by other groups, all of which suggest that the evidence for superheavies is weaker than before.

Most recently new observations were reported at a special session on superheavies at the APS Nuclear Physics Division meeting at Michigan State University on 29 October. Earlier, relevant work had been reported at the Conference on Physics with Heavy Ions held at Caen, France in September.



Portion of x-ray spectrum from monazite inclusion #19A measured at Harwell. The tin lines are from fluorescence. The line due to the K_α line of antimony and the L_α line of element 124 should both have appeared near 26.3 keV with a peak yield about 200 counts above background. No line is seen. For details see Florida State University Tandem Accelerator, Annual Report, 1976.

In the original experiment,[1] the Oak Ridge–Davis–Florida State group had studied giant halos in mica samples from Madagascar. These giant halos could not be accounted for by thorium or uranium decays. At the center of each halo is a monazite inclusion [$(Ce,La,Th)PO_4$]. The experimenters bombarded the inclusions with 4.7–5.7-MeV protons from the Florida State Tandem Van de Graaff. They then looked for characteristic L x rays from elements with Z greater than 105, whose energies had been calculated theoretically, and which could not be attributed to any known x ray or nuclear gamma ray. According to the original paper, the evidence for element 126 was most convincing because they saw a 27.25-keV line from the $L_{\alpha 1}$ line of 126 from five out of the six crystals studied and also because there were no known alternatives for that line. Evidence for elements 116, 124 and 127 was considered

continued on page 19

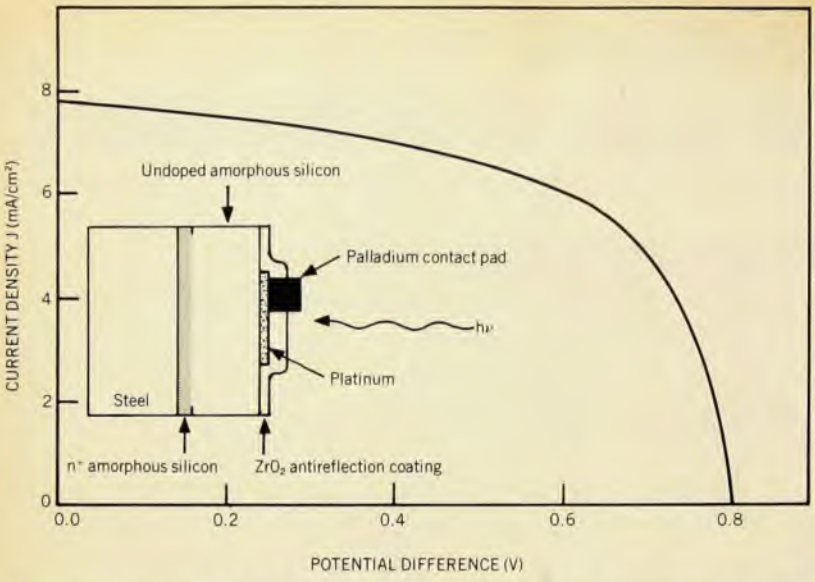
Amorphous-silicon doping brightens solar-cell picture

The success of solar cells in powering space vehicles is well known, but for earthbound applications much more stringent economic constraints apply. This is one reason for the great interest in photovoltaic devices based on doped amorphous semiconductors, which promise to be much easier and cheaper to manufacture in quantity than single-crystal cells.

David E. Carlson, Christopher R. Wronski, Alfred R. Triano and Ronald E. Daniel of RCA Laboratories (Princeton) reported achieving power-conversion efficiencies as high as 5.5% with glow-discharge amorphous-silicon cells, at the Baton Rouge IEEE Conference of Photovoltaic Specialists held in mid-November. They used doped amorphous silicon in two configurations:

- A p–i–n junction, in which the p-doped (acceptor) layer is separated from an n-doped (donor) layer by an undoped (intrinsic) layer,[1] and
- A Schottky diode, in which the p layer is omitted, its role taken over by a charged region near the metal electrode,[2] the "Schottky barrier." It was the latter technique that gave the 5.5% efficiency; the p–i–n cells were 2.5% efficient.

Amorphous semiconductors were first successfully doped in 1969, when Robert C. Chittick, J. H. Alexander and Henley F. Sterling of Standard Telecommunications Laboratories (Harlow, UK) reported doping amorphous silicon by a glow-discharge technique. Using this technique, Walter E. Spear and Peter G. Le Comber of the University of Dundee (Scotland) made intensive investigations of amorphous silicon doped with both donors and acceptors.[3] This led in January 1976 to their report,[4] together with Marc H. Brodsky of the IBM Research Center (Yorktown Heights) and Stewart Kinmond (Dundee), of the development of a p–n junction of amorphous silicon obtained by the decomposition of silane (SiH_4). They achieved doping with phosphine (PH_3) and diborane (B_2H_6), in amounts varying from 5 ppm to 1%.



Current-voltage characteristic of a platinum Schottky-barrier cell being illuminated by sunlight of 65 mW/cm^2. The solar cell has about 5.5% efficiency, as reported by David Carlson and his RCA associates at the Baton Rouge conference. The graph shows a short-circuit current density of 7.8 mA/cm^2. The inset diagrams the Schottky-barrier structure used in the experiment.

Other early work in related phenomena include the photoluminescence studies of Detlef Engemann and Roland Fischer (University of Marburg, Federal Republic of Germany). Recently John C. Knights of the Xerox Palo Alto Research Center, using the glow-discharge process, has studied amorphous silicon doped with arsenic.[5]

It was the Le Comber–Spear publication that forced the RCA group's hand; according to Carlson, although they had been studying doped amorphous silicon since 1974, they were inhibited by patent considerations from publishing their results earlier. To make the p–i–n structures, the RCA workers doped the silane-gas discharge with diborane (for the p layer) and phosphine (for the n layer), at atomic concentrations of about 1%. The cells are about 1 micron thick, most of the thickness being that of the intrinsic layer. They are deposited on glass coated with transparent electrodes of indium tin oxide, and have an aluminum contact evaporated onto the n layer. Although the silane partially decomposes, the amorphous-silicon film is believed by most workers to retain a considerable amount of hydrogen, as supported by the work of Hellmut Fritzsche and his coworkers at the University of Chicago. William Paul and his collaborators at Harvard University have systematically studied the effect of hydrogen in amorphous germanium, in which, they showed, it compensates dangling-bond defects.

Jacques Pankove and Carlson also reported electroluminescence produced by these p–i–n junctions.[6] Because it is the inverse process, this study helps in the understanding of the photovoltaic properties, in addition to its potential application as a light source.

To make the Schottky-barrier devices, the RCA group deposited them on a stainless steel substrate for low contact resistance. After depositing the n-doped layer (about 300 Å), they added an undoped layer of amorphous silicon 1 micron thick and followed it with a semitransparent platinum film. The high-work-function metal causes electron depletion in a layer 0.3–0.4 microns thick in the semiconductor to produce the Schottky barrier. Antireflection coatings of ZrO_2 or Si_3N_4 about 450 Å thick were used at the front surface.

The Schottky devices are, in Carlson's estimation, an order of magnitude cheaper to produce than other current solar cells. He feels that the device's ideal efficiency of 15% can be approached by reducing the series resistance at the contacts and increasing the hole-diffusion length in the undoped layer.

Many other concepts in research, development and production techniques are in the works; some of them were reported on at the Photovoltaic Specialists' meeting. The concepts include:

▸ Harold Hovel and Jerry Woodall of IBM (Yorktown Heights) and workers at Rockwell International and Hughes Research Laboratories have improved the efficiencies of photocells of gallium arsenide to over 22%.

▸ Polycrystalline silicon cells are being improved at AEG Telefunken and Wacker Chemie in West Germany. Many labs are also working towards lowering the cost of single-crystal silicon.

For example, at Simulation Physics, Inc. (Burlington, Mass.), ion implantation has been used together with annealing by electron-beam pulses to produce single-crystal solar cells with 12% efficiency. The entire process, from starting wafer to finished solar cell, takes only two minutes and uses very little total energy. Its low cost makes this one of the most promising techniques of the ones reasonably close to actual production, Hovel feels.

▸ John D. Meakin and his collaborators at the Institute of Energy Conversion, University of Delaware, reported obtaining efficiencies of 7.8% for a CdS-Cu_2S cell, with a good likelihood of going up to 10%; with $Zn_xCd_{1-x}S$–Cu_2S cells they expect to obtain 15%.

▸ For producing solar cells of very large area at very low cost, a chemical-spray process developed by John F. Jordan of Photon Power (El Paso) makes films on a float-glass substrate a few microns thick, with 5% efficiency. Jordan expects the firm to begin production "shortly." Assuming low-quantity production (10^6 ft^2/year), he anticipates a production (not selling) cost of $425 per kilowatt for the 2-ft-square cells, with lower cost as production increases. He also expects the efficiency to rise to 8% soon.

▸ A novel production process is vapor deposition in space. In this technique, a General Electric development for NASA, silicon layers of very high purity are to be deposited in the extremely high vacuum behind the wake shield of a station.

▸ Also being investigated are such promising long shots as organic semiconductors (by Exxon and IBM Research), although the efficiencies of these are still less than a tenth of a percent.

We asked solar-energy expert Peter E. Glaser of Arthur D. Little, Inc. to comment on the impact of research toward the development of economical solar cells for terrestrial use. Glaser agrees that there is a greater commercial significance in the production potential of reasonably efficient (greater than 10%) amorphous solar cells than in the high efficiency of single crystals, the quantity production of which at low cost is "difficult to visualize." However, Glaser was impressed by the great variety of work reported at the photovoltaicists' meeting. "It is too early to tell whether silicon, gallium arsenide, cadmium sulfide or some other material will turn out to be best, particularly when some can be combined with solar concentrators," Glaser said.

A number of companies—Optical Coatings Laboratory, Spectralab, Solar Power, Solarex and others—already produce silicon solar cells for unattended power supplies at a cost of about $15 000 per kilowatt. There is some doubt, Glaser told us, whether the objective of ERDA's National Photovoltaic Conversion Program, to reduce this to $500/kW by 1985, can be achieved, unless major advances occur and the market expands substantially. Carlson, on the other hand, was more optimistic. Furthermore, both

Hovel and Glaser point out that concentrating sunlight may considerably improve the outlook for reaching this goal.

The efficiencies of thin-film photovoltaic devices are still far below those achievable with single crystals; their present 5–8% level of efficiency is only on the ragged edge of usefulness. Cells of low efficiency require larger areas and therefore more costly structures. Studies of the tradeoffs between efficiency and the costs of producing, mounting and connecting the cells, done at Brown University, indicate that economical operation requires at least 10% efficiency.

Practical systems must take into consideration losses due to storage systems, such as batteries, to make energy available during nights and overcast days. For some small-scale applications—pumping of irrigation water, heat pumps for cooling, TV for developing countries—some of which do not require energy storage, photovoltaic power already looks promising. The use of solar cells for central power plants with steady base-load output is still remote, however. Large installations present practical problems such as shading of large areas, structures that must withstand high winds, snow, dust and hail, and suitable means of energy storage.

The field of photovoltaic conversion is in a creative ferment and, while it is too early to tell which system will win the horse race, a lot of interesting work is being done. —HRL

References

1. D. E. Carlson, C. R. Wronski, Appl. Phys. Lett. **29,** 671 (1976).
2. C. R. Wronski, D. E. Carlson, R. E. Daniel, Appl. Phys. Lett. **29,** 602 (1976).
3. W. E. Spear, P. G. Le Comber, Phil. Mag. **33,** 935 (1976).
4. W. E. Spear, P. G. Le Comber, S. Kinmond, M. H. Brodsky, Appl. Phys. Lett. **28,** 105 (1976).
5. J. C. Knights, Phil. Mag. **34,** 663 (1976).
6. J. I. Pankove, D. E. Carlson, Appl. Phys. Lett. **29,** 620 (1976).

Dubna believes it has produced element 107

A group at the Joint Institute for Nuclear Research in Dubna, headed by Georgi Flerov, says it has synthesized element 107. If verified, the Dubna observation would be the highest-Z manmade element. It is the latest in a long series of attempts to extend the periodic table, made sometimes at Lawrence Berkeley Laboratory, sometimes at Dubna, sometimes at both. (More recently a group at Oak Ridge has joined the competition.) One priority dispute, over the discovery of element 104, is being settled by having a Dubna experimenter observe the Berkeley experiment and a Berkeley experimenter observe the Dubna experiment. Two years ago Berkeley and Dubna both announced the discovery of element 106 (PHYSICS TODAY, November 1974, page 19). In the case of element 107, however, Berkeley is not claiming to have found 107, although Albert Ghiorso told us they would like to start looking for it this year.

The new Dubna experiment, reported[1] in *JETP Letters,* was done by Yu. Oganesyan, A. G. Demin, N. A. Danilov, M. P. Ivanov, A. S. Il'inov, N. N. Kolesnikov, B. M. Markov, V. M. Plotko, S. P. Tret'yakova and Flerov. The crucial thing in the experiment is cross bombardment, which leads to the observation of element 105. Using a 310-cm cyclotron, the experimenters obtained a beam of Cr^{54} ions (with a charge state of +8) with energy 290 MeV. They bombarded a target of $_{83}Bi^{209}$ and at first found a spontaneously fissioning emitter with a halflife of 5 sec. They reasoned that such a halflife was too long for element 107 and that the activity was probably associated with element 105.

So they tried other bombardments, using different combinations of targets and projectiles that would add up to 105: $_{83}Bi^{209} + _{22}Ti^{50}$ and $_{82}Pb^{208} + _{23}V^{51}$, and observed a 5-sec activity, which they then attributed to element 105. Revamping their equipment to look for shorter halflives, they found one of about 2 msec. The results of experiments with the reactions $Bi^{209} + Cr^{54}$, $Pb^{208} + Mn^{55}$ and $Tl^{205} + Fe^{58}$ have indicated that the yield of this activity exhibits the regularities expected for element 107. They also say that the yield of this emitter correlated in all the experiments with the yield of the 5-sec activity. They interpret this result to mean they were seeing spontaneous fission of the isotope $_{105}X^{257}$, produced after the alpha decay of $_{107}X^{261}$. Furthermore, the Dubna group says that element 107 has a branching ratio for alpha decay of about 80% and a spontaneous-fission branching ratio of about 20%.

Objections. The Dubna experiment has been criticized by some experimenters because the alpha energy has not been measured. In addition, Ghiorso says that the Dubna claim about the branching ratio is "astounding considering that no alpha particles have been observed." He says that he and his collaborators hope to look for element 107 this year by using a F^{19} beam from the 88-inch cyclotron. They would search for the reaction $Cf^{249}(F^{19},4n)_{107}X^{264}$.

Recently a group of scientists published[2] a manifesto, presumably in response to past Berkeley–Dubna feuds and the more recent controversy over the existence of element 126 and others in mica (see page 17). The basic criterion for discovery of a new chemical element, they observe, should be the establishment of the atomic number. Ideally, chemical identification should be made. "If the new element is observed through its decay by high-energy alpha-particle emission or spontaneous fission, or both, the chemical identification can be confined to separation from all known elements with atomic number greater than lead." Unfortunately, they note, such chemical identification has not been feasible in reported discoveries of the last several manmade elements.

Another scheme, the manifesto says, is to identify characteristic x rays produced when the isotope of the new element decays. Still another is to prove a genetic decay relationship through an alpha-particle decay chain in which the resulting product has been previously established. This method, however, depends on measuring "the half life and precise, unique energies of the alpha particles of the new isotope."

The manifesto argues that detection of a spontaneous-fission activity and measurement of its halflife "cannot *per se* establish that an element with a new atomic number has been produced." Ghiorso points out that the work on element 107 does not appear to meet the criteria set forth. Flerov told us that his group "regards this manifesto with irony." —GBL

References

1. Yu. Ts. Oganesyan, A. G. Demin, N. A. Danilov, M. P. Ivanov, A. S. Il'inov, N. N. Kolesnikov, B. N. Markov, V. M. Plotko, S. P. Tret'yakova, G. N. Flerov, JETP Lett. **23,** 277 (1976).
2. B. G. Harvey, G. Herrmann, R. W. Hoff, D. C. Hoffman, E. K. Hyde, J. J. Katz, O. L. Keller Jr, M. Lefort, G. T. Seaborg, Science **193,** 1271 (1976).

Superheavies in mica

continued from page 17

less convincing, the group had said.

The report was exciting for many reasons. Manmade elements had been known only as high as element 106, although now a Dubna group has reported evidence for element 107 (see this page). Although there have been indications of heavier elements in meteorites, the presence in naturally occurring mica of elements in the range $Z = 116$ to 126 suggests that these superheavies are primordial. This would have great consequences for thinking about astrophysical element formation. Furthermore, the observations suggested two islands of stability, a hitherto unexpected possibility.

Cerium gamma ray. In July a group at Florida State began a systematic effort to find all possible nuclear gamma rays that might be produced by 4.7–5.7-MeV protons but had not yet been catalogued. They bombarded all the stable naturally occurring elements with atomic number greater than eight, except the noble gases, using a proton beam of 5.7 MeV. X rays and gamma rays were measured in the range 10–100 keV. The experimenters,