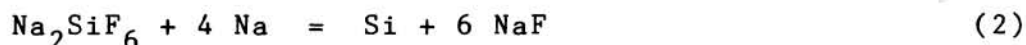


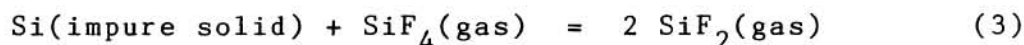
PRODUCTION OF ELECTRONIC GRADE LUNAR SILICON BY
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Waldron (1) has proposed to extract lunar silicon by sodium reduction of sodium fluorosilicate derived from reacting sodium fluoride with lunar silicon tetrafluoride. Silicon tetrafluoride is obtained by the action of hydrofluoric acid on lunar silicates. While these reactions are well understood, the resulting lunar silicon is not likely to meet electronic specifications of 5 nines purity. Dale and Margrave (2) have shown that silicon difluoride can be obtained by the action of silicon tetrafluoride on elemental silicon at elevated temperatures (1100-1200 C) and low pressures (1-2 torr). The resulting silicon difluoride will then spontaneously disproportionate into hyperpure silicon and silicon tetrafluoride in vacuum at approximately 400 C. On its own merits, silicon difluoride polymerizes into a tough waxy solid in the temperature range from liquid nitrogen to about 100 C. It is the silicon analog of teflon. Silicon difluoride ignites in moist air but is stable under lunar surface conditions and may prove to be a valuable industrial material that is largely lunar derived for lunar surface applications.

The most effective driver for lunar industrialization may be the prospects for industrial space solar power systems in orbit or on the moon that are built with lunar materials. Such systems would require large quantities of electronic grade silicon or compound semiconductors for photovoltaics and electronic controls. Since silicon is the most abundant semimetal in the silicate portion of any solar system rock (approximately 20 wt%), lunar silicon production is bound to be an important process in such a solar power project. Lunar silicon can be extracted (1) as follows:



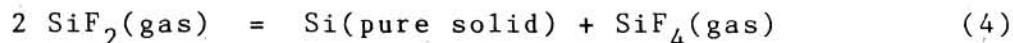
Reactions (1) and (2) are components of a hydrofluoric acid (HF) process for digestion of lunar soils that can extract all the major lunar metals except calcium, separate all the major lunar oxides, and generate lunar oxygen (1,3). Both reactions proceed at about 700 C and (2) is self sustaining once ignited (4). However the product silicon is likely to contain unacceptable levels of sodium impurity for electronic applications. That can be addressed by reacting the silicon with SiF_4 at 1100 - 1200 C and pressures below a few torr to obtain SiF_2 (2) as follows:



As a gas, SiF_2 has a lifetime of approximately 150 sec but

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it can be condensed to a reddish brown polymer-(SiF₂)_x-in liquid nitrogen which converts to a tough white waxy solid at room temperature. SiF₂ ignites spontaneously in air but is stable in vacuum. And it can be disproportionated at 400 C in vacuum to yield hyperpure silicon and SiF₄ by the reverse of reaction (3):



Minor perfluorosilanes of the form --SiF_{2n}-- are also generated by the disproportionation. Gaseous products in (4) can be recycled to (3).

Reaction (3) and its reverse can of course be used to purify silicon extracted by any process such as carbon or aluminum reduction of silica. Hydrogen reduction of SiF₄ is another approach to silicon extraction. While it is very unfavorable thermodynamically (3), the reduction may proceed by electric discharge or the excitation of hydrogen plasma (5) and could produce silicon as pure as the product of reaction (4). Alternatively, hydrogen reduced silicon can be purified by the disproportionation of SiF₂.

Silica and aluminum, as well as SiF₄ and hydrogen, are products of the lunar HF process. Accordingly, fluoride processing makes lunar silicon abundantly available. In addition, significant quantities of fluorine may be available on the moon. Phosphates are widely disseminated in the lunar samples, up to one modal percent in KREEP rocks and soils. Further, a large fraction of lunar phosphates are fluorine rich apatites, some exceeding 3% F (6). Such phosphates can be beneficiated by dry electrostatic processes (7) and could become substantial sources of lunar halogens.

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