



Non-Confidential Description

Advances in the Deposition of Amorphous Silicon Films and Printed, Flexible Electronic Circuits

Technology Case: RFT-039

Invention Summary

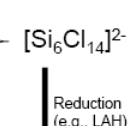
This patented technology provides a compound and process useful in the production of amorphous silicon films, such as those used in photovoltaic applications, as well as in the creation of printed, flexible electronic circuits. The technology involves a process of producing compounds containing a tetradecachlorocyclohexasilane dianion. These compounds are prepared by contacting trichlorosilane with a reagent composition comprising a tertiary polyamine. The resulting dianion can be chemically reduced to liquid cyclohexasilane (CHS), a stable compound useful in the silicon-based industries described herein.

Application

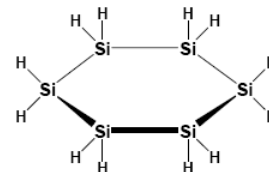
- Used to produce liquid cyclohexasilane (CHS), a stable compound useful for silicon-based applications, including:
 - Liquid CHS can be easily printed using direct write techniques
 - Used as a feedstock material for semiconductor wafers and photovoltaics
 - Useful in the deposition of amorphous silicon films
- Resulting CHS is easily purified via distillation processes
- Improvements in yield and process flow have led to the development of cyclohexasilane that is cost-competitive with very little waste or by-products.

Liquid Cyclohexasilane Enabling Innovative Processing of Si-based Electronic Materials

Stable, non-flammable,
non-explosive, hygroscopic,
colorless crystalline solid
DOT-compliant shipment
MSDS available



Multigram synthesis
1. U.S. Patent 5,942,637
2. JACS, 2001, 123, 8117-8.



Colorless liquid
Bp. 80 °C/0.02 Torr

Easily purified
via distillation

Potential Applications Include:

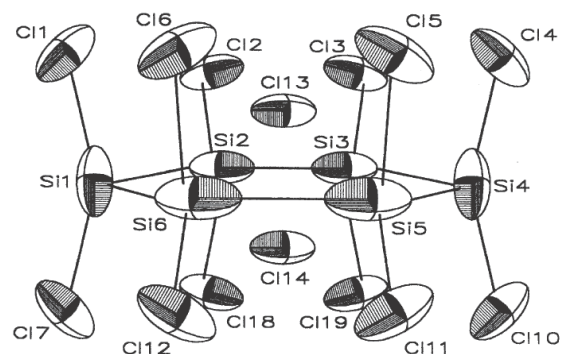
SiH₄ Replacement for CVD

- Si, SiN, or SiO_x thin film
- Potentially faster growth rates
- Potentially lower deposition T

Direct-Write Printed Electronics

- Si-based transistors
- Si-based diodes
rectennas
solar cells

Above: Overview and properties of dianion and liquid CHS. **Below:** The molecular structure of the tetradecachlorocyclohexasilane dianion, the precursor in the process of making liquid CHS.



Patents

This technology has an issued US patent 5,942,637 with foreign patent rights issued/or preserved in the United Kingdom, Germany, France, Italy, and Japan. This technology is available for licensing and partnering opportunities.

Lead Inventor



Philip Boujock, PH. D.

VP for Research, Creative Activities and Technology Transfer

Dr. Philip Boudjouk was named NDSU's first Vice President for Research, Creative Activities and Technology Transfer in March 2000. Boudjouk has been active as a teacher, researcher, and member of the NDSU Department of Chemistry faculty since 1973. He earned his bachelor's degree at St. John's University, Jamaica, N.Y., and his doctorate in chemistry from the University of Wisconsin-Madison. Prior to his appointment at NDSU, he held a Teaching and Research Fellowship at the

University of California at Davis for two years. During his tenure as Vice President, research expenditures at NDSU have increased from \$44 million to \$115 million.

Boudjouk's research career has focused on organometallic chemistry with emphases on organosilicon compounds, polymers, catalysis, materials research, and sonochemistry. He has more than 130 refereed publications in international journals and holds 19 patents. He has been the thesis advisor for 20 Ph. D. students and 22 M.S. students. Boudjouk has been a guest lecturer at over 40 universities in Europe and Asia.

From 1992-2000, Boudjouk served as Project Director for the North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR). The ND EPSCoR program is widely recognized for its success in promoting and administering millions of dollars in federal contracts with research faculty throughout the North Dakota University System.

He has received numerous awards for teaching and research, including being named the Chamber of Commerce Distinguished Professor (1985) and University Faculty Lecturer (1985). He received the first annual Research Award from the College of Science and Mathematics (1992) and in 1998 he was named the Jordan A. Engberg Scholar, the first endowed professorship at NDSU.

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