Early Materials Launched Modern-Day Spacecraft Capabilities

Materials used to construct spacecraft have their roots in early rocketry, which most scholars agree can be attributed to early Chinese inventors. The fuel for early rockets was gunpowder. Its first recorded use is found in a recipe from the *Wu Ching Tsung Yoa*, circa 1040 A.D. The ancient Chinese manuscript *T-hung-lian-kang-mu* refers to the first use of rockets in 1232 A.D., during a siege laid to the South China city of Kai-Fung-Fu by the Mogul hordes led by Ogdai, son of Ghengis Khan.

In 1240, eight years after the battle of Kai-Fung-Fu, an anonymous scholar described the use of saltpeter, a naturally occurring form of potassium nitrate, known as the "snow of China." Saltpeter, along with sulfur and charcoal, was a key ingredient in making gunpowder. Another anonymous scholar referred to these gunpowder-fueled rockets as "Chinese arrows."

The craft of rocketry evolved slowly. One reason for this slow growth was the instability of gunpowder, which tended to explode before it was expected to. At the beginning of the nineteenth century, an officer in the British Royal Artillery, William Congreve, discovered that gunpowder moistened with alcohol could be hammered safely without igniting. His work allowed rockets to achieve ranges of up to 2,000 meters. But even with this newfound stability for gunpowder, rockets were limited to lightweight, high-performing weapons that could not compete with the accuracy and explosive power of artillery charges until the invention of the liquid-fueled rocket.

On March 16, 1926, the space age began when Robert Goddard launched a small liquid-fueled rocket for a short but tremendously significant flight. With the start of World War II, the pace of rocket science began to accelerate: Germany tested a 14-ton V-2 rocket, launched on October 3, 1942, only 16 years after Goddard's first flight; fifteen years later, on October 4, 1957, the Soviet Union launched Sputnik into Earth orbit; and twelve years after that, on July 22, 1969, U.S. spacecraft landed on the Moon. But these astonishing successes were not without difficulties.

The materials for propulsion presented a major problem with early rocketry, specifically erosion of the engine nozzle by hot exhaust gases. Exhaust gases from the combustion process in the engine had to be channeled through a properly contoured nozzle so as to control the thrust. The nozzle had to be highly resistant to any thermal expansion or erosion that would change the size or shape of the nozzle opening, so as to prevent modification of the burning characteristics of the propellant. Thus, the nozzle was required to be temperature resistant, light in weight, erosion and thermal shock resistant, with high structural strength. An early choice of material was graphite, which was widely-used and permitted the evolution of early liquid-fueled rockets.

In Germany, in 1942, graphite was also used for the exhaust vanes in V-2 rockets. Because of graphite's susceptibility to oxidation, as well as its tendency to erode due to the metal additives in solid propellants, graphite was replaced by other materials, such as molybdenum, silicon nitrate, and tungsten. By the 1950s, another material, boroaluminosilicate fibrous glass-reinforced plastic, was being used to construct high-pressure solid propellant rocket motor casings. Such reinforced plastic casings were significantly more lightweight than earlier ones.

Reinforced plastic was not only used for launching mechanisms, but also was applied to space capsules, recovery gear, structural parts, dielectrics, electrical insulation, and reentry bodies. For example, during reentry a number of schemes for thermal protection were used such as ablation, radiation cooling, high-temperature parachutes, inflated drag brakes, inflatable lifting surfaces, or a combination of these. Ablative designs used plastics that chemically changed their composition and sublimed when they were heated.

Present advanced technology initiatives such as the National AeroSpace Plane, a joint Department of Defense-NASA project to field a Single-Stage-To-Orbit spacecraft that can take off from a runway and accelerate to space, are spearheading programs in materials science to encourage further advances in this area.

DOUG BEASON

FOR FURTHER READING: Earl R. Parker, ed., "*Materials for Missiles and Spacecraft*," (McGraw-Hill, New York, 1963); Canby Courtland, *A History of Rockets and Space* (Hawthorn, New York, 1963); *Spacecraft Design and Operational Problems; Aerospace Technology Conference, 1985* (Society of Automotive Engineers, Warrendale, PA, 1986).

LIBRARY

Fluorine-Carbon and Fluoride-Carbon Materials

T. Nakajima, editor
(Marcel-Dekker, New York, 1994, 416 pages, $165.00)
ISBN: 0-8247-9286-6

Fluorine-Carbon and Fluoride Carbon Materials, edited by Tsuyoshi Nakajima, is an excellent and authoritative reference work dealing with fluorine graphite intercalation compounds (GIC's), main- group and transition metal fluoride GICs, B/C/N analogues of GICs, fluorinated fullerenes, carbon and modified carbon anodes for elemental fluorine production, and the relatively new superhydrophobic nickel-tetrafluoroethyleneoligiomer composites. The list of contributors is a literal "who's who" of recognized experts in their various fields, including Neil Bartlett, Marius Chemia, Yong-Bo Chong, Didier Devilliers, Mildred S. Dresselhaus, Morinobu Endo, Rika Hagiwara, John H. Holloway, Jean-Paul Issi, Masayuki Kawaguchi, Tsuyoshi Nakajima, Tetsuro Tojo, Alain Tressaud, Yuko Tsuya, and Rachid Yazami. The authors, in their

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respective chapters, discuss and elaborate on new and significant contributions to their areas, using concise, easy-to-read language devoid of all but the most essential jargon. The references are as recent as any monograph can possibly be and are carefully chosen to illustrate the important generalities and pertinent specifics of the topic. The English is clear and understandable despite its second-language status for the majority of contributors. It is an easy read even for non-experts, despite the technical nature of the subject and the significant, informative content.

The text contains over 550 reference citations, some as recent as March 1994, and contains more than 250 tables and drawings. The C_xF and MF_x GIC's are authoritatively discussed: synthesis, structure, bonding, and physicochemical, and thermodynamic properties. A very comprehensive chapter on C_xF physical properties—including electrical, electronic, magnetic, thermal, and optical properties—is probably the best-written entry of this area for chemists and material scientists. The chapter on fluorinated fullerenes, though short, is comprehensive and up-to-date in this fast-moving, new area. The electrochemistry of C_xF GIC's and their battery applications are discussed, as is the tribology (lubricating properties) of CF_x and $(C_2F)_x$. The chapter on carbon and modified-carbon anodes for elemental fluorine production is unique in its presentation and discussion of an area which until now was highly fragmented, shrouded in industrial secrecy or presented in such generalizations as to be informationally useless to those outside this interesting but esoteric field. The chapter on lubrication with $(CF)_x$ is clear and concise and addresses both lubrication capabilities and limitations. The relatively new area of superhydrophobic composites is a valuable introduction into an infant field likely to be technologically important.

On a typographical note, three errors were found. On page 242, $C_{60}F_y$ should be $C_{70}F_y$; and on page 388, $-CF_2- > -CF_2-$ and $-CF_3 > -CF_3$ presumably should be $-CH_2- > -CF_2-$ and $-CH_3 > -CF_3$.

As a practicing chemist whose interests lie in the organic chemistry of elemental fluorine, highly fluorinated cage molecules, and direct fluorination in general, I was initially skeptical of the book's usefulness except for the short chapter on fluorinated fullerenes. The great number of figures and tables usually indicate a dull read. Nothing could have been further from the truth. Having read all 393 pages of text, I feel the book has brought me to the leading edge of a field which, though old, is undergoing an exciting renovation and expansion as modern techniques are brought to bear on its outstanding challenges. The book will be a valuable resource for chemists, physicists, materials scientists, industrial technologists, and others who have a need to explore or utilize the unique properties of fluorine-carbon and fluoride-carbon materials. Those who cannot justify a personal copy should be sure their library has one.

Reviewer: James L. Adcock is a chemist at the University of Tennessee in Knoxville and a specialist in elemental fluorine and its reactions. His work in fluorinated cage molecules and the synthetic and mechanistic behavior of elemental fluorine in organic chemistry is well-known in the field.

UPCOMING CONFERENCE

IUMRS-ICA-95 to be Held in Korea, Oct. 17–20

The Materials Research Society of Korea is organizing the International Union of Materials Research Society's 3rd International Conference in Asia to be held October 17–20, 1995, at the Korea Exhibition Center in Seoul, Korea.

The scope of the conference includes experimental and theoretical studies on the various materials and materials characterization. A special session called "Advanced Materials for Semiconductor" will be organized to provide a forum for discussing the progress of state-of-the-art technologies in semiconductor processing. This session is divided into four parts:

- Etching and Cleaning: low damage and highly selective etching process, high density plasma generation technology, contamination control, and gas phase and wet cleaning technique;
- Metallization: silicide process, diffusion barriers, interconnection materials, metal-MOCVD process development, and electromigration and stress migration;
- Dielectric Materials: deposition process of dielectric, piezoelectric, pyroelectric, ferroelectric thin films, fundamental phenomena, characterization, and integration and application of dielectrics; and
- Semiconductor Materials: Si-based epitaxial growth, wide bandgap semiconductors, materials for flat panel displays, and III-V and II-VI compound semiconductors.

The other four topics of the conference are as follows:

- Functional Materials: including superconducting materials, magnetic materials, ionic conductors, battery materials, sensor materials, and shape-memory alloys;
- Structural Materials: including lightweight metals, high temperature materials, high wear-resistant materials, high strength and toughness ceramics, and metal/ceramic matrix composite;
- Polymer Materials: chemistry and physics of polymer materials, high performance polymer, and polymer composites; and
- Materials Characterization: spectroscopic analyses (UV, IR, Raman, AES, XPS, PL, RBS), and imaging techniques (SEM, STM, AFM, STEM).

Tadahiro Ohmi, from Tohoku University in Japan, and Kye-Hwan Oh, from Hyundai Electronics Industries Co, Ltd., in Korea, are the keynote speakers. The chair of the conference is Jin-Tae Song, from Hanyang University in Korea.

Two special events are planned. The conference will hold a banquet on October 18 in the Rose Room at Hotel Inter-Continental. On October 20, an industrial visit and tour is scheduled at Hyundai Electronics Industries Co., Ltd., and Korean Folk Village.

English is the official language of abstracts, full papers, and presentations at the conference. Conference proceedings will be distributed on-site.

For more information, contact Hyeong-Joon Kim, Secretariat IUMRS-ICA-95, Department of Inorganic Materials Engineering, Seoul National University, Seoul 151-742, Korea; phone 82-2-880-7162, fax 82-2-884-1413. □

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