Intermetallics in Space instrument making

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Introduction

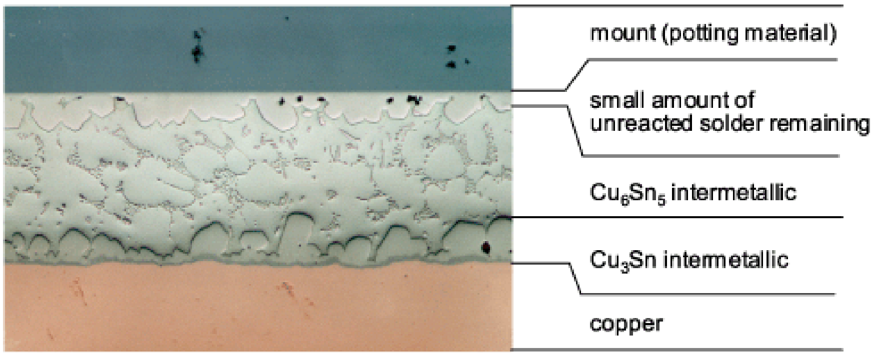
New space equipment design for exploration our universe requires new materials that can withstand the stresses of space flight (high temperature and pressure, vibration loads on the stage of takeoff, low temperatures of space, deep vacuum, radiation exposure, microparticles, etc.) and at the same have sufficient low specific weight.

Revolutionary solutions in the development of advanced space technologies XXI century can provide a new class of construction materials - intermetallic compounds (chemical compounds, titanium-aluminum, nickel-aluminum, and others.). These materials are low density (3.7 ... 6.0 g / cm3) and have a high heat resistance (up to 1200 ° C), high corrosion resistance properties, heat resistance and durability.

Intermetallic alloys based on titanium can operate until the temperature of +850 ° C without protective coverings

Intermetallics are concerned with all aspects of ordered chemical compounds between two or more metals, in particular with their applications.

When a solution solidifies, alloys of metals which have a limited mutual solubility may form new phases at certain ratios. These new phases possess crystal structures different from either component and are named intermetallic compounds. The properties of intermetallics generally differ from those of the component metals, often less metallic, with reduced density, ductility, and conductivity [1].



Picture 1 - Intermetallic formation between copper and tin

Intermetallics have properties of both metals and ceramics, and their mechanical properties are intermediate between metals (which are generally softer and more ductile) and ceramics (which are generally harder and more brittle). The dominant bonding in ceramics is covalent and ionic, as opposed to metallic bonding. Intermetallics contain both metallic and covalent bonds, depending on the constituent metals. Because of their intermediate position, the properties of intermetallics can be strongly influenced by small changes in the system (i.e., variations in the microstructure can result in changes in strength and ductility over a considerable range).

Research and problems

A great deal of work has been done in the last 10 to 15 years to develop and characterize intermetallics and to develop processing technologies. The need for low density, high performance alloys for use in the components of airframes and turbine engines.

The main problem with many intermetallics is that they can have extremely low ductility at normal temperatures. It means that before they can be used as structural materials, intermetallics must be modified to improve their ductility and strength and to make them more resistant to oxidation and corrosion. In addition, processes must be developed for preparing and processing these materials into usable shapes.

For high temperature structural applications (e.g., turbine and internal-combustion engine components, process tooling). Aluminides were chosen because of their potential for excellent oxidation and corrosion resistance at high temperatures. In addition, using ductile aluminides as structural materials could reduce the nation's dependence on strategic materials like chromium.

From the beginning, the research and development of intermetallics has been multidisciplinary and has included basic research to increase the understanding of alloy properties, improve alloy design and properties, develop first principles theory, investigate advanced analytical techniques for characterization, and research processing and fabrication in areas such as casting and welding.

The focus of the initial program was on Ni3Al, one of the few materials known to exhibit a significant increase in yield strength with increasing temperature (from ambient conditions to about 800°C). The remarkable properties of nickel-based superalloys used in aircraft turbine engines result from the presence of Ni3Al. These attractive attributes provided the impetus for the development of Ni3Al alloys as structural materials for commercial applications.

Intermetallics have given rise to various novel materials developments. Some examples include alnico and the hydrogen storage materials in nickel metal hydride batteries. Ni3Al, which is the hardening phase in the familiar nickel-base superalloys, and the various titanium aluminides have also attracted interest for turbine blade applications, while the latter is also used in very small quantities for grain refinement of titanium alloys. Silicides, intermetallics involving silicon, are utilized as barrier and contact layers in microelectronics [2].

Application

One of the very important applications for intermetallic compounds is their using in the gas and jet turbine engines. The rotating components in the rear sections of the engines can experience temperatures in excess of 1500 °C coupled with high loading stresses. Currently, the materials used comprehensively for this demanding application are nickel-based superalloys.

At present, materials scientists all over the globe are in constant hunt for an advanced intermetallic compound that would be capable of superseding the properties of the current nickel based superalloys. The search has now been going on for almost two decades, and its pace has picked up over the last five years in order to cope with the demanding design criteria of newer generations of gas or jet turbine engines [3].

Scientists from the Pohang University of Science and Technology (South Korea) have created a new alloy of iron, aluminum and nickel.

Lightweight, but durable materials in high demand and are used extensively in the aerospace and automotive industries. South Korean scientists have succeeded in developing a material that is not inferior to their properties titanium or carbon fiber, but costs 10 times cheaper. The key point here is the use of intermetallic - several chemical compounds of metals with a fixed number of atoms on each of them. Nickel and aluminum intermetallic compound able to receive an equal number of atoms of the two metals. These crystals have a thickness of only a few nanometers and effectively penetrate into the steel structure, giving it the strength of titanium [4].

Developers are confident that in the near future they will begin alloy used in mass production - for example, in the automotive industry. Scientists have only solved the problem of protecting the melt from oxidation, since the usual protective layer of molten silicate flux in this case cannot be used - it reacts with the aluminum upon cooling.

A new high temperature aerospace material has proved to be elusive so far, however, the candidate materials have to ascend from this peculiar and exciting class of materials, the intermetallics.

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First Artificial Earth satellite

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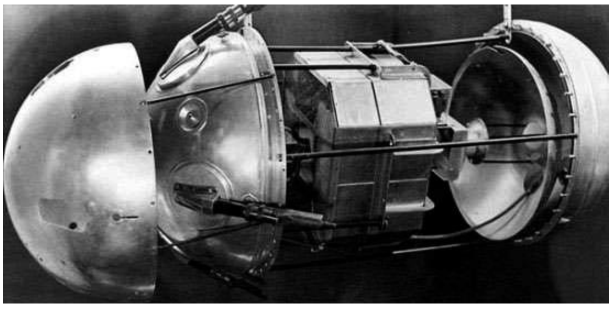
History changed on October 4, 1957, when the Soviet Union successfully launched first artificial satellite, called ‘Sputnik-1’. It was 58 cm diameter and 83 kg weight metal sphere that transmitted simple radio signal [1].

Designing and construction of sputnik:

Designing of SS-1(simple satellite) was began in November, 1956 and in September, 1957 state testing was finished. Design was performed by NII-4 of State Defense Department. Sputnik was designed as very simple device with 2 transmitters for trajectory measurements. Range of transmitters was chosen such way that radio fans could receive its signal. Inside sphere were placed power supply, radio transmitter, thermal relay, sensors of temperature and pressure, onboard control system, cable network [2].



Picture 1 - Internal device of satellite

Designing and construction of rocket

The R-7 was 34 m long, 3.02 m in diameter and weighed 280 tons. It had two stages, powered by rocket engines using liquid oxygen (LOX) and kerosene and capable of delivering its payload up to 8,800 km with an accuracy (CEP) of around 5 km. The initial launch was boosted by four liquid rocket boosters making up the first stage, with a central sustainer engine powering through both the first and the second stage. Design work began in 1953 at OKB-1 in Kaliningrad with the requirement for a two-stage missile of 170 tons with a range of 8,000 km carrying a 3,000 kg payload. Following first ground tests in late 1953 the initial design was heavily reworked and the final design was not approved until May 1954 when more than 100 design proposals were reviewed. In 1954 draft project was completed. First launch was May 14, 1957. Fire broke out right away