The COSMA Story - An innovative Idea to Commercial Reality

The use of modifying agents to improve the castability and mechanical properties of aluminium silicon alloys is well documented. Sodium is widely accepted as being the most efficient modifier but practical problems associated with its use have meant that other modifiers such as strontium have become popular.

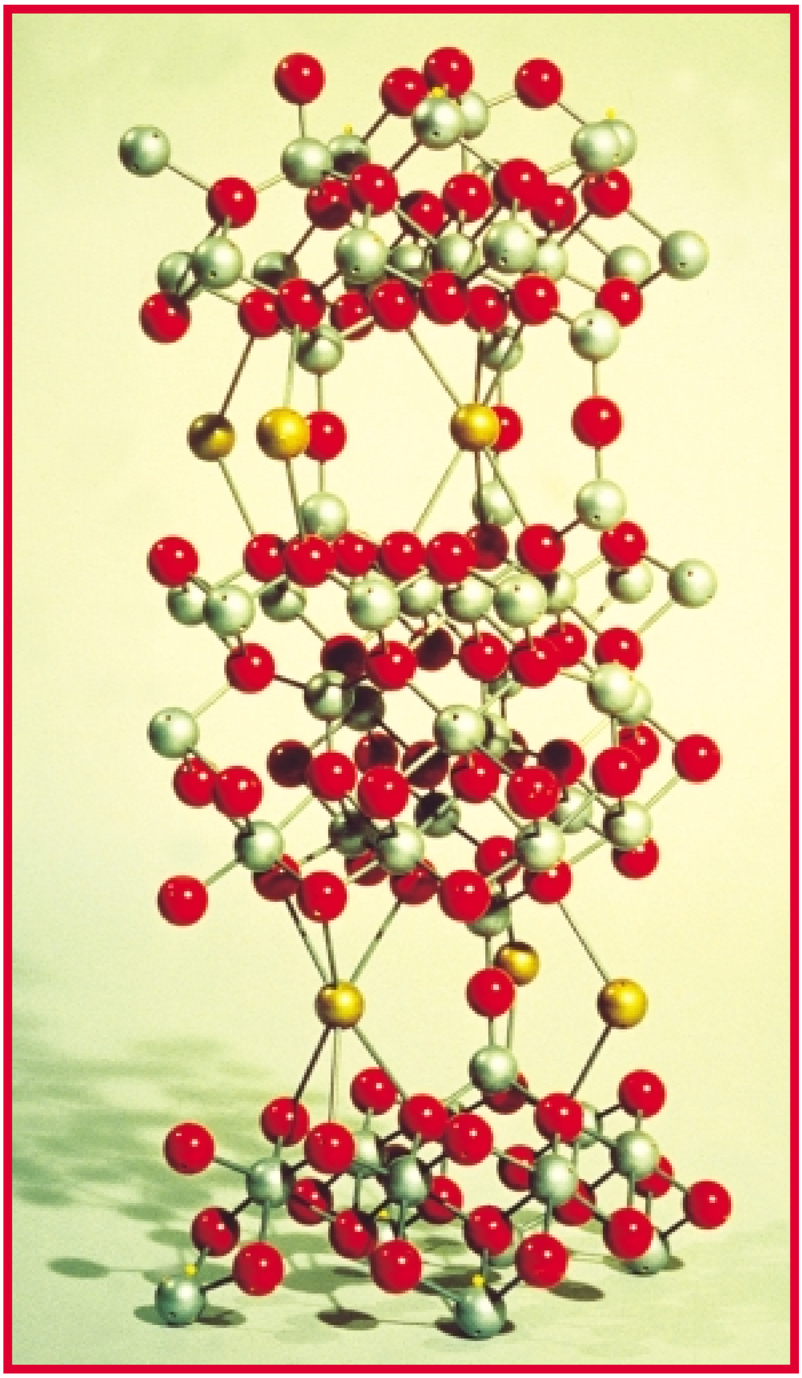

Figure 1 - Crystal structure of beta alumina

COSMA is a completely novel method for generating and adding sodium to aluminium alloys. The process is based on the electrolysis of a sodium salt which produces metallic sodium by transferring sodium ions through a beta alumina solid electrolyte. COSMA gives the foundryman all the benefits of sodium but without the usual disadvantages. In addition, it offers the possibility of a far greater degree of control over the modification process than has ever been possible before.

The COSMA project is an example of how new technologies can be brought to the foundry industry. It is a story of how the academic world and industry can work together to develop a commercial reality from an innovative idea.

1. Introduction

The story starts around a hundred years ago when a ceramic called beta alumina found use in the glass industry. It was first thought to be a simple allotrope of alumina but in the 1920's it was discovered that the lattice structure consisted of spinel blocks with sodium positioned in the planes between the blocks. (Figure 1) Beta alumina contains around 5% to 10% sodium and it is a very good sodium ion conductor.

In the 1960's the Ford Motor Company in the US was searching for a solid electrolyte material to form a battery to replace the internal combustion engine. The company tried a vast number of materials and a Dr Kummer discovered that beta alumina had an extremely high conductivity. Immediately, companies throughout the world, Ford, GE, Chloride, Brown Boveri and others started serious studies of the sodium sulphur battery (Figure 2).

This battery technology made use of the fact that when a voltage is applied across beta alumina the sodium ions move through the lattice from the anode to the cathode. When they arrive at the cathode they pick up an electron and are transformed to metallic sodium. If a ready source of sodium ions is placed on one side of the ceramic then a continuous flow of sodium metal will be produced at the other side.

In 1970 Dr Fray realised that the sodium sulphur battery process had the potential to be used in the

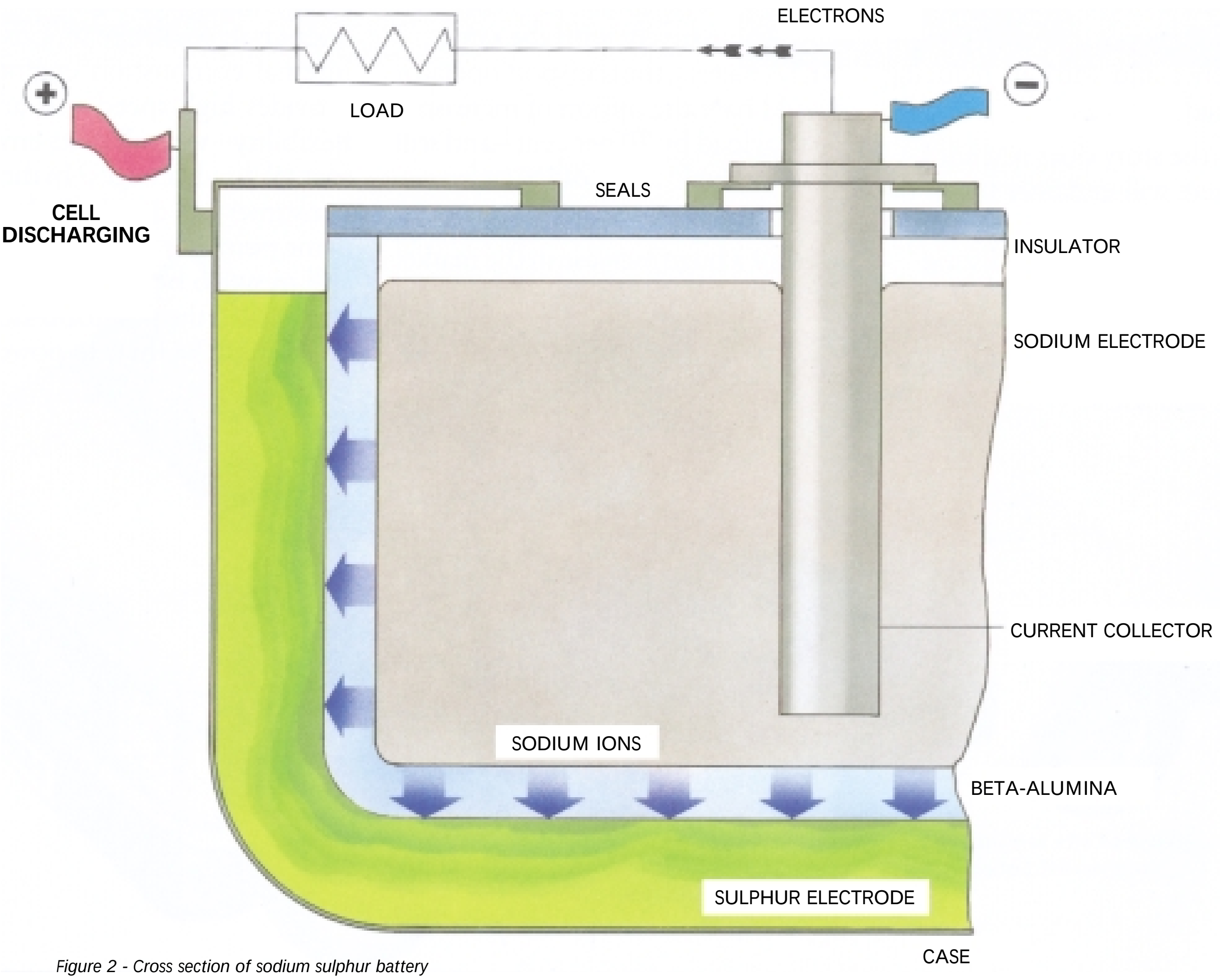

Figure 2 - Cross section of sodium sulphur battery

metallurgical industry. His first idea was to add sodium to zinc by the electrolysis of cheap sodium salts and transferring the sodium ions produced through the beta alumina into the melt by means of an electric current. (Figure 3) Unfortunately this idea was not taken up industrially but in 1971 Dr Fray moved to the academic world where he continued to investigate the application of beta alumina in the metallurgical industries. During this time the first experiments were conducted using beta alumina to add sodium to aluminium.

This idea remained on a laboratory scale until 1993 when a three year EC funded Brite Euram project was initiated to develop the process further. It was towards the end of this project that John Hack of Foseco FS spotted the potential of this technology for Foseco.

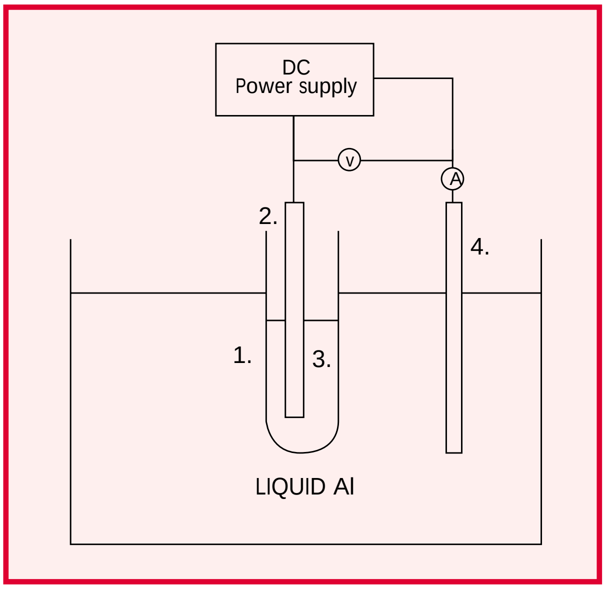

Figure 3 - Schematic of original COSMA concept

1. solid electrolyte
2. electrode
3. Na source
4. graphite electrode

2. Project COSMA

The COSMA process, (an acronym for the **CO**ntrolled addition of **S**odium **M**odifier to **A**luminium alloys), started life in 1993 with four partners from both academia and industry.

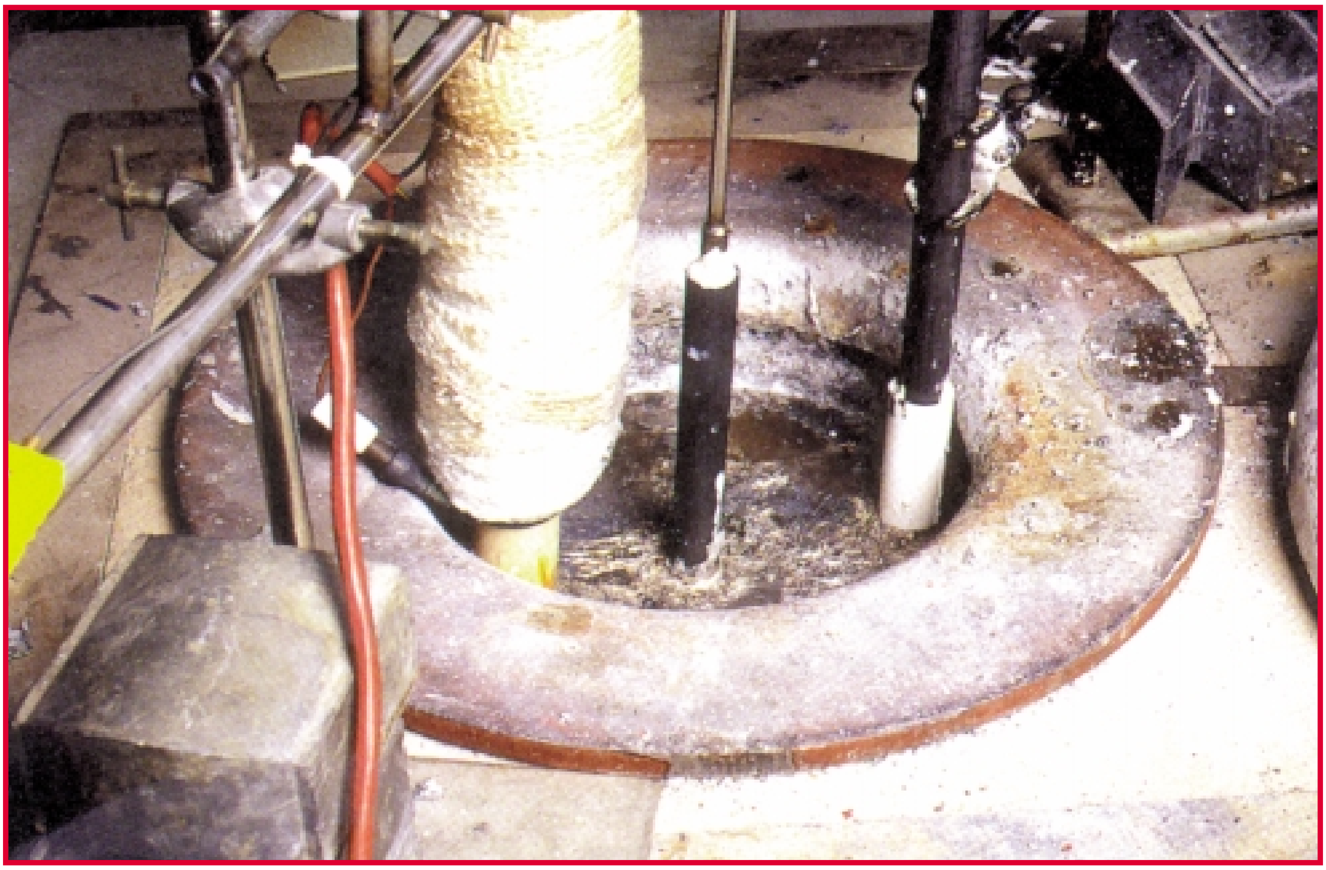

Figure 4 - Original COSMA concept under foundry test

The partners were; Leeds University in the UK (Dr Fray), Vito, a Belgian research organisation and two Belgian aluminium companies, Hoogovens and Lemmerz. This first three year project which ended in 1996 was able to demonstrate the technical feasibility of the COSMA process but several problems remained before COSMA could be considered as a commercial proposition. (Figure 4) The remaining issues, both technical and commercial, that needed to be resolved were;

- Selection of the sodium source
- Electrolysis conditions and cell design
- Design, construction of the COSMA unit
- Industrial testing

Two of the original partners wanted to continue work on COSMA and Foseco and another Belgian company, Verhaert Design & Development, joined with them to form a new consortium to conduct a second project. This project started in 1996 and after a further 4 years work the first industrial COSMA unit is ready for extended foundry testing.

The four partners and their respective roles in the project were; the University of Cambridge, (where Dr Fray now worked) and Vito who would conduct fundamental research and laboratory testing into aspects of cell operation. Verhaert, (Belgium) who were responsible for the design and manufacture of the technological demonstrator and Foseco who would conduct field trials of prototype and marketing of COSMA to the aluminium casting industry.

2.1 Selection of Sodium Source

One of the most important tasks of the research phase was the selection of the sodium source best suited to the COSMA process. Initially a preliminary selection of possible sodium sources was made based on the following physiochemical and safety requirements;

- Melting point - the sodium salt needs to be molten to allow the electrolysis to take place. The higher the melting point of the salt the hotter the operation of the COSMA unit with the attendant material selection and design problems

- Boiling point - to minimise evaporation of the salt at operating temperatures

- Nature of reaction products - Solid reaction products would build up in the system and impede further reaction. Gaseous by products would be preferred

- Safety aspects - the sodium salt needed to be capable of being handled safely. The toxicity of the electrolysis reaction products was also a major consideration

- Commercial availability and price - the chosen salt must be economically viable to make COSMA a commercial success

The two major phases in this work were carried out by Cambridge University and Vito. A literature survey established which salts were theoretically capable of being used and this was followed by laboratory experiments to determine the melting point, electrical conductivity and reaction products of the various candidates.

Many different sodium salts including binary and tertiary eutectic mixtures of salts were evaluated before the best source of sodium was identified.

2.2 Electrolysis Conditions and cell design

The working principle of COSMA is based on the electrolysis of a sodium salt and the transfer of the sodium ions produced through a beta alumina tube. The rate at which metallic sodium is produced is governed by Faraday's law;

$$m = \frac{M \cdot i \cdot t}{n \cdot F}$$

with m = mass of formed Na (g)
M = atomic mass of Na = 23
i = applied current (A)
t = time of electrolysis (s)
n = number of electrons involved in the reaction = 1
F = Faradays number = 96500 (C)

The higher applied current the greater the rate at which sodium is produced. However, the maximum applied current depends on several factors such as the maximum current density and the effective surface area of the beta alumina tube.

This posed a significant challenge because the current density normally used in batteries was very low and would not be able to produce sodium at a rate suitable for foundry application. Increasing the current density to achieve a higher rate of sodium production was possible but it shortened the life of the beta alumina tubes to such an extent that the process would not have been economically viable. A considerable amount of effort by Cambridge and Vito in collaboration with the suppliers of the beta alumina tubes went into establishing the optimum electrolysis conditions and improving the cell design.

The result of this work is an electrolytic cell that is capable of producing sodium at an industrial rate and that has a working life that makes COSMA a very economic process.

2.3 Design, construction of the COSMA unit

Although the electrolytic cell is the heart of process there was a lot of work required to design a COSMA unit that would be efficient, reliable and safe in the foundry environment. This part of the project was undertaken by the industrial partners, principally Verhaert but with collaboration of Foseco to understand the requirements and the conditions in which foundries were likely to operate COSMA.

The design and construction of the COSMA unit went through three basic phases. Firstly a so called breadboard technological demonstrator, secondly a development model and finally a production prototype.

The technological demonstrator was based on the know how developed during the first COSMA project. It's purpose was to evaluate how the system performed in an industrial environment in terms of the lifetime of component parts, ease of use for foundry personnel, safety of operation and the efficiency of sodium additions. Most of the work was conducted in the laboratories at Vito but foundry trials were also an important part of this stage of the project.

All the knowledge gained from the technological demonstrator was then incorporated in the next design, the development model. This model was designed as a modular construction and was intended to be the basis for the final production design. This involved increasing the number of beta alumina tubes to obtain the sodium output required industrially and uprating various aspects such as heaters and insulation. The development model was used for testing in a foundry environment to determine the efficiency of sodium additions.

After further minor modifications the production prototype was designed and built (Figure 5).
The improvements in it's design were essentially cosmetic with outer panels added to cover the functional parts of the unit. This model will now be used for further industrial trials and demonstrations to introduce COSMA to the foundry industry.

Figure 5 - COSMA production prototype

Figure 6 - COSMA development model in foundry trials

2.4 Industrial testing and marketing

The industrial trials were carried out using the development model COSMA unit placed on top of a Foseco FDU. (Figure 6). The results gained (Table 1) showed sodium addition efficiencies of around 40%, much higher than traditional methods of sodium addition.

Current per beta alumina tube (Ampere)	Measured sodium Addition (ppm)	Theoretical sodium Addition (ppm)	Efficiency (%)
50	26	51	51.9
100	24	102	23.3
100	63	102	61.3
150	56	154	36.3
150	63	154	40.8
overall efficiency →			**41.1%**

Table 1

2.5 Future work

Work continues to develop the COSMA concept further by incorporating sodium sensors to give a fully automated and controllable system. More applications for COSMA will be developed such as treating and maintaining sodium levels in holding furnaces and low pressure furnaces.

Acknowledgements

Thanks go to all involved in the COSMA project at Cambridge University, Ionotec, Vito, Verhaert and Foseco. Their hard work and innovative solutions to the various technical problems that arose has been truly impressive.