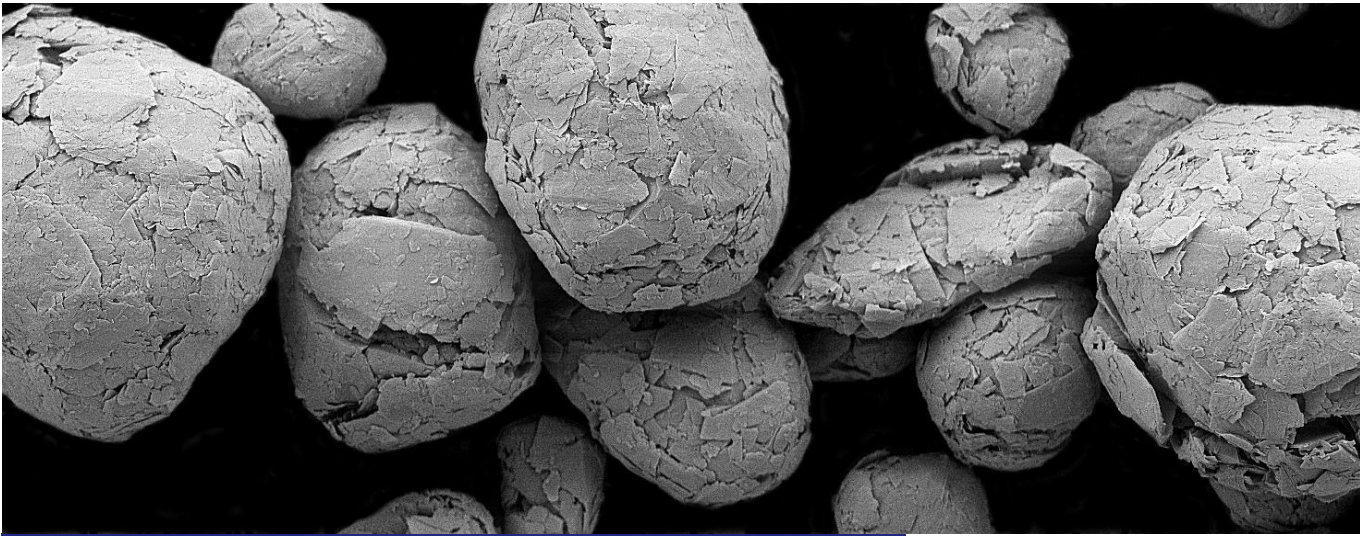




Spherical Graphite

Introduction

Lithium Ion Batteries

Spherical Graphite

ANZAPLAN Services

Highlights

- *Booming demand for lithium ion batteries*
- *Western world depends on China's spherical graphite exports*
- *27% CAGR for spherical graphite in the last six years*
- *ANZAPLAN is the only European based company offering spherical graphite evaluation services and pilot plant sample production*

1. Introduction

Graphite is the anode material of choice in the booming battery business offering superior charge efficiency, energy density and cell capacity. It is either used in its natural form, as synthetic graphite or as a modified natural, so called spherical graphite (SG) material finding widespread application in lithium-ion batteries used in grid-attached residential and industrial energy storage solutions, electric vehicles (EVs) as well as portable consumer electronics devices.

Considering the fact that lithium ion batteries consumes 10 – 15 times more graphite than lithium and in the light of forecast compound annual growth rates in said markets there is a tremendous need especially for high grade graphite materials in the market.

2. Lithium Ion Batteries

Graphite is used as an active material in the anode of Li ion batteries because it has the capability of taking up and releasing lithium ions in between its layer structure during charge and discharge processes.

In Li-ion batteries a number of different metal oxide materials (such as NCA, NMC, LFP, LCO, LMO, CSG and others) are used as cathode materials while the anode is typically made of graphite which is coated on a copper foil.

The rise of Li-ion batteries is due to superior properties over other secondary (or rechargeable) batteries including high energy density, compact design, no memory effects, high open-circuit voltage, low self-discharge, high cycle life and environmental benefits.



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The battery market is a rapidly growing sector with demand forecast to grow at approximately 9 % CAGR based on anticipated lithium ion battery demand (Source: Industrial Minerals).

Growth in the market is mainly driven by increasing demand in grid-attached energy storage solutions, hybrid and electric vehicles and as power source for mobile electronic devices including laptops, tablets, cell phones and power tools.

Lithium ion battery is set to dominate the **emerging grid-attached storage market** and the grid-connected PV energy storage market. 90% of proposed grid storage projects in 2014 are set to be supplied by Li-ion technology. Panasonic forecasts a striking 74.9% CAGR for lithium-based grid-scale energy storage with a share of 37.6% in the forecast 2020 lithium ion battery market dominated by grid and renewable energy storage (Frost and Sullivan, 2013).

The second most rapidly growing market is that for **electric vehicles (EV)**, including hybrid (HEV), plug-in hybrid (PHEV) and battery electric vehicles (BEV) for which Panasonic foresees a growth in lithium ion batteries of 16.9% CAGR. The Tesla gigafactory alone is estimated to boost the graphite demand by as much as 30 % in 2020. For 2020, Frost and Sullivan predict an EV market share of 30.0% in the lithium ion battery market.

The third largest demand of lithium-ion batteries, which has already seen a spike in demand is in **consumer electronics** such as laptops, smartphones, power tools and handsets which according to Frost and Sullivan will absorb a 23.9% market volume share in 2020.

3. Spherical Graphite

Compared to typical flake graphite, spherical graphite offers a number of advantages when used in battery applications.

Well rounded spherules have a low specific surface area (BET), thereby minimizing capacity losses. Additionally they allow for a more efficient packing and increase the tap density and overall volumetric energy capacity of the anode. A well-rounded spherule can be coated more evenly than sub-rounded or angular grains, which adds to the efficiency of the battery anode.

Three different coated spherical graphite specifications in the following key sectors are forecast to drive graphite demand growth:

- d_{50} = 23 microns: grid storage
- d_{50} = 16 microns: electric vehicles
- d_{50} = 10 microns: hybrid vehicles and consumer electronics



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Synthetic graphite has traditionally been the major anode material (55%) with natural graphite forming the balance (45%). However, an opportunity exists for spherical graphite to displace synthetic graphite in the anode market. Use of natural graphite is increasing due to:

- quality improvements
- lower cost: synthetic graphite sells for around US \$20,000 per ton whilst coated spherical graphite currently sells for between US \$7,000 to US \$10,000 per ton.

Graphite flotation concentrates are partly sold directly to end-users in a number of sectors including foundries and refractories as main markets. Usually a portion of that ROM concentrate is processed into high-purity graphite (99.9+%) by chemical and physical processes for various demanding high value applications including expandable graphite used in gaskets, seals etc. and spherical graphite used in Li ion batteries.

Only graphite which can economically be shaped into spherical graphite (spheroidized) and purified is a suitable feed stock for the production of spherical graphite. This is where ANZAPLAN's extensive processing know-how comes into play.

ANZAPLAN has developed a special technology which has been applied successfully to a number of different natural flake graphite concentrates. SG (see Fig. 1) was produced at high yields, meeting and exceeding the 30% yield of SG commonly reported for a feedstock flake graphite, and matching with those of typical reference products in the market.

As a finishing step, spherical graphite for anode production is coated with a carbon layer via chemical vapor deposition (CVD) to further reduce its specific surface area creating a homogeneous and smooth surface.

For the electrode production the coated SG is dispersed in a solvent. Conductive agents (carbon black) and a binder (usually a polymer) are added. The resulting ink is deposited on a copper foil by conventional coating or by other printing techniques. After evaporation of the solvent in a continuous drying tunnel, a dry electrode is obtained. For decreasing the porosity of the electrode, it is compressed by a roll pressing (illustrated in Fig. 2).

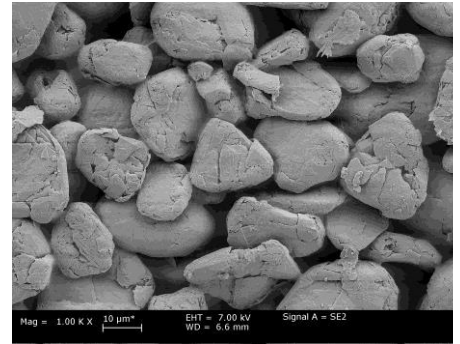


Figure 1: SEM image of SG produced at ANZAPLAN as base material for anode production

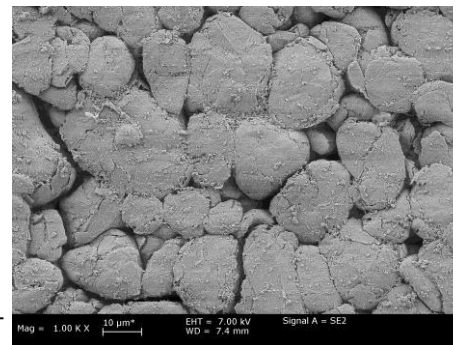


Figure 2: SEM image of a commercial Li-ion battery anode consisting of a dense SG layer including binder and carbon black

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ANZAPLAN is the only European based company offering a one stop shopping concept for graphite projects. It covers the whole value chain from drill core analyses over process development and pilot scale sample production up to engineering of a processing plant.

ANZAPLAN offers an advanced test service package, including a comprehensive evaluation of spheroidization properties and final purities to be achieved. Our downstream service portfolio will support you so you can participate in the booming high value battery market.

Due to an extensive industrial network, close contact to the anode industry and deep knowledge of markets, ANZAPLAN is your ideal competent and independent partner for graphite projects with services tailored to your requirements all along the graphite value chain.

We invite you to contact our experts at Dorfner ANZAPLAN to discuss your needs in detail so we can set up a tailored service package for you.

4. ANZAPLAN Services

Dorfner ANZAPLAN and its laboratory are accredited by the DAkkS accreditation chamber who is a signatory to the multilateral agreements of EA, ILAC and IAF for mutual recognition. Therefore analyses and testing by ANZAPLAN are internationally accepted. In addition services by Dorfner ANZAPLAN are certified and approved by ISO 9001:2000, DIN EN ISO/IEC 17025:2005 and ISO 14001 for chemical and physical analyses, process engineering, research and development, for basic materials, industrial mineral products and systems, and environmental technology. Our expertise allows us to competently and confidently assess graphite deposits and ultimately approve future products with potential end-user customers. We provide know-how in the design and optimization of innovative tailor-made processing plants and all our services are proven by internationally accepted certifications (ISO 9001:2000 and ISO 14001).



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