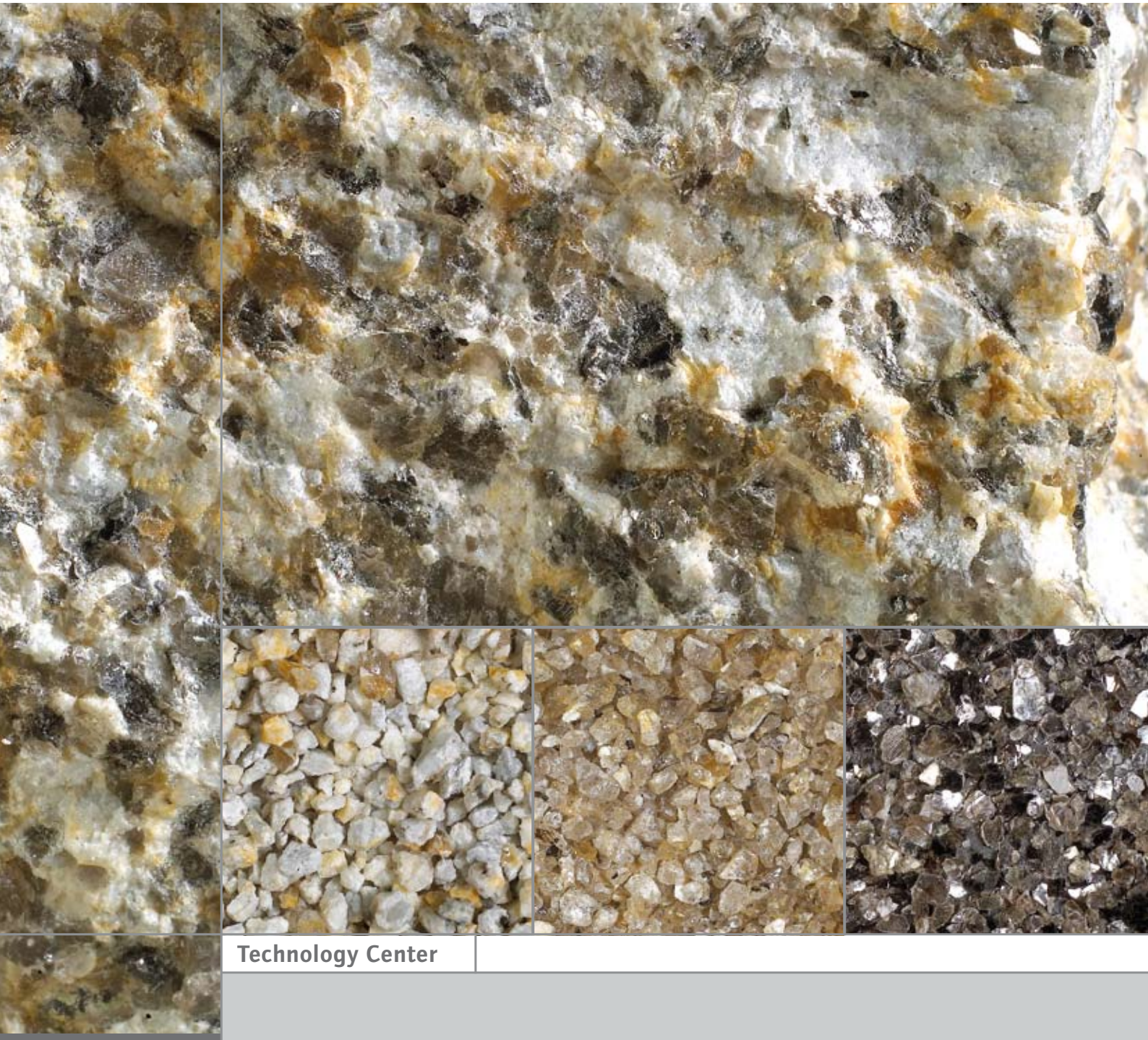
AMMANN



Technology Center

selFrag-Lab Laboratory Fragmentator

Selective Fragmentation of Materials
by Means of Electric Pulsed Power

selFrag

selFrag: A new Fragmentation Technology

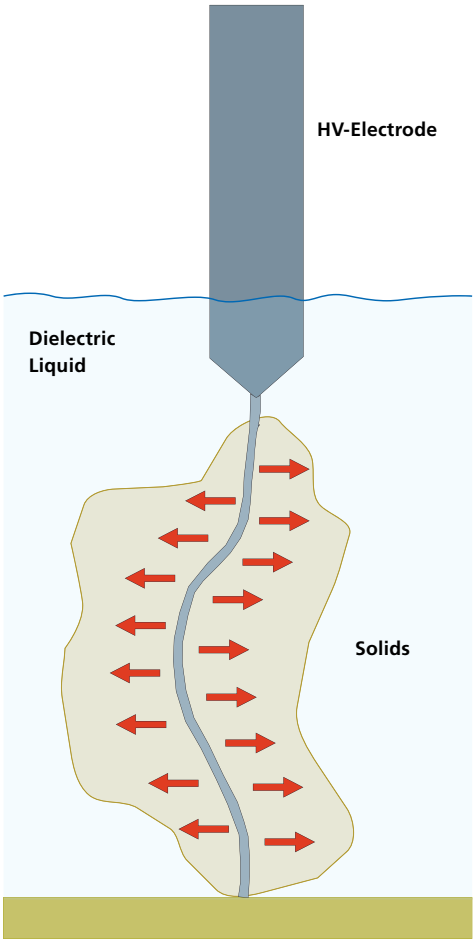


Figure 1: Fragmentation by high-voltage discharge

selFrag stands for Selective Fragmentation, an electric pulsed power process. High-voltage (HV) discharges are applied for the fragmentation, desintegration or disaggregation of solids.

Historical Background

The use of HV pulsed power technology for the fragmentation of rocks goes back some 30 – 40 years. Russian scientists were the first to conduct systematic research in this field.

In 1995 the German Karlsruhe Research Center (Forschungszentrum Karlsruhe, FZK) embarked on a far reaching R&D programme to explore possible industrial applications of selective fragmentation. Since then FZK has built several specially designed pilot plants and has investigated the fragmentation of many different materials in the field of mineralogy, raw materials and composites. FZK has demonstrated the advantages as compared to mechanical fragmentation and the great potential for the commercialization of this technology.

The Ammann-Group, under a world wide license from FZK, is now making this patented technology commercially available.

Principles of selFrag

Selective fragmentation is based on the principle of applying pulsed HV discharges on inhomogeneous, non-conducting solids.

In the course of only a few micro seconds a HV discharge (up to some 400 kV, with an energy of 10 – 300 J per cm) is deposited in the discharge plasma channel, which initially measures only a few µm. Pressures of up to 10^{10} Pa at temperatures of approx.10^4 K are generated in the process. They have an effect similar to chemical explosives (e.g. TNT) initiated in a borehole. As a result high pressure impulses propagate through the solids causing them to be destroyed due to mechanical stress (Fig.1). Reflections from acoustic inhomogeneities induce tensile stress in areas of grain boundaries, inclusions or interfaces of composites, causing the material to break predominantly at these inhomogenities. Consequently composite materials are fragmented into their components with a high degree of selectivity.

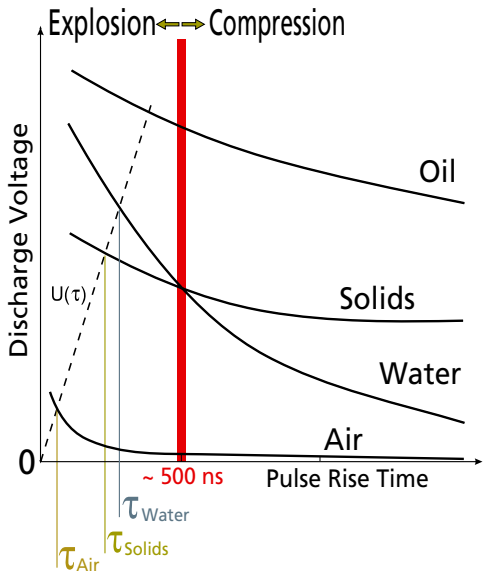


Figure 2: Breakdown strength of various materials as a function of the pulse rise time

In all applications the solids must be submerged in a dielectric liquid such as water, oil or other organic liquids. For practical reasons water is the liquid of choice for most applications.

Materials exposed to electric tension exhibit variable breakdown strength as a function of the pulse rise time, i.e. the time it takes for the high-voltage to reach its peak. A HV discharge occurs first in the material with the lowest breakdown strengths. For example, when the pulse rise time is less than 500 ns the breakdown strength of water exceeds that of most "classical electric insulators", such as ceramics, glass, and many minerals. Thus the discharge occurs first in the solids (Fig. 2).

Municipal waste incineratior slag treated 120 seconds in a selFrag-Lab, demonstrating the high degree of selectivity of the process.

selFrag-Lab Laboratory Fragmentator

Purpose: Sample Processing

selFrag-Lab is intended for the selective fragmentation of composite materials, mineralogical and geological samples in the one kilogram range. It offers the possibility of selectively liberating target specimens while minimizing the by-production of fines.

Equipment

The aim of the design was to achieve simplicity of operation. selFrag-Lab comes as a stand-alone piece of equipment designed for easy installation in a typical mineral laboratory environment. The equipment consists of a HV power supply, a HV pulse generator, a process chamber, a portable process vessel and a lifting table for easy loading and unloading of the process vessel. The process chamber, a confined space containing the working electrode is enveloped by an outer shell specially designed to guard against sound and electromagnetic emissions. To keep the unit compact, the HV components are insulated with oil and gas and walled with a steel shielding. To ensure safe operation the HV parts of the equipment are protected by safety interlocks. The operation occurs in batch mode.

Operating Principle

The HV pulse generator is continuously charged by the HV power supply. When the predetermined voltage is reached, the energy of the HV pulse generator is discharged from the HV working electrode through the solid sample to the grounded bottom of the process vessel. This charging and discharging cycle repeats itself at a given frequency until the pre-selected number of pulses (discharges) has been reached.

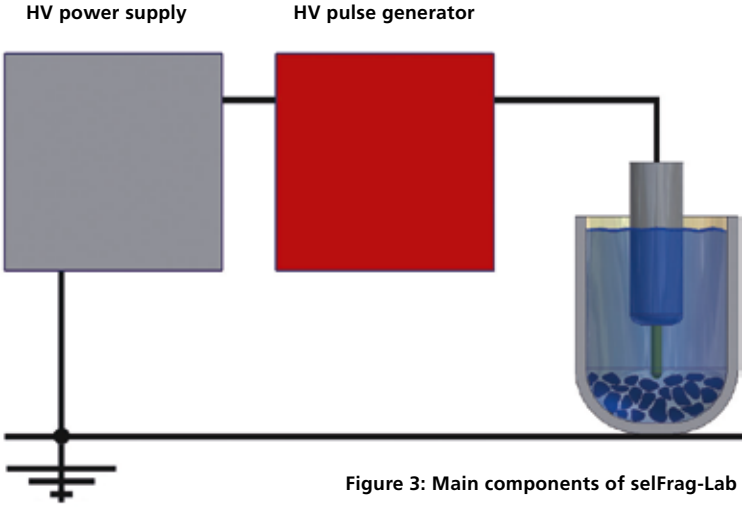


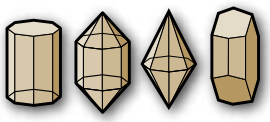
Figure 3: Main components of selFrag-Lab

Handling

The portable process vessel is first charged with the desired amount of samples and then filled with water. Next it is placed onto the lifting table in the loading section. Then the interlocking safety door is closed. After setting the desired experimental parameters concerning energy and number of pulses on a touch panel, the operator can start the fragmentation process. The lifting table moves the process vessel into position inside the reaction chamber. After 10 to 120 seconds the process is completed. The lifting table lowers the process vessel to the loading section, the safety interlocks are released and the door can be opened to retrieve the vessel with the fragmented sample.

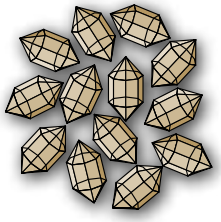
Advantages of the selFrag Process

Selective Fragmentation has Tremendous Advantages in Comparsion with Mechanical Processes

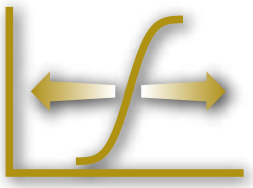


- Predominant fracturing along grain boundaries

- Liberation of morphologically intact minerals or micro-fossils
- Recovery of mono-mineral fragments
- Very clean surfaces of liberated minerals
- Minimal damage to liberated target specimens



- High yield of available target specimens
- Preservation of natural particle size distribution
- Narrow particle size distribution and choice of mean value
- Single step processing – from rock to micro grain



- Only a few minutes to process one kilogram of sample
- Semiautomatic programmable processing
- Very low production of undesired fines below 50 µm
- No dust production

- Virtually no (cross-) contamination of samples
- No moving parts and hence virtually no wear
- Easy cleaning by simple scrubbing and rinsing
- Higher speed and quality of overall analytical process

The selFrag process offers new possibilities of analyzing mineral samples for science and material testing.

Comparison with Mechanical Crushers

	Jaw crusher	Rotary impact crusher	Roll crusher	selFrag-Lab
Fracturing behavior	random (not preferentially along grain boundaries)	random (not preferentially along grain boundaries)	only partially selective	highly selective along grain boundaries
Production of fines < 50 µm	high	high	high	very low
Mineral intergrowth in the < 50 µm fraction	high	high	high	virtually none
Dust production	high	very high	high	none
Contamination	high	high	low	very low
Wear	high	high	moderate	very low

Fields of Application

- Geoscience research
- Exploration of mining sites
- Analysis of composition of raw material
- Analysis of waste as secondary raw material

Typical Applications

- Recovery of individual minerals for general geochemical and chronologic analyses.
- Liberation of accessory mineral components of any type of rock.
- Characterization of diamond indicator minerals
- Characterization of platinum group minerals
- Characterization of sulfide minerals
- Characterization of gold minerals
- Liberation of unbroken micro-fossils

Applications

Application Granite

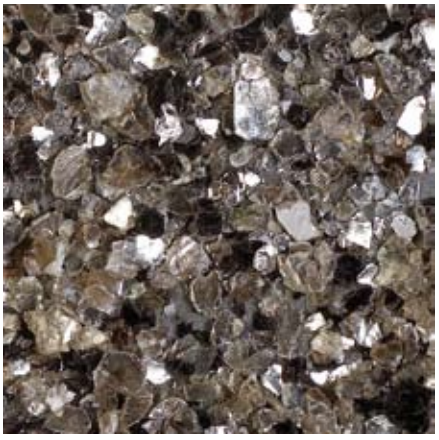
Granite

Feldspar

With the selFrag-Lab granular rocks can be selectively fragmented into the different mono-mineral fractions with high yield and only small amounts of composite multi-mineral grains.

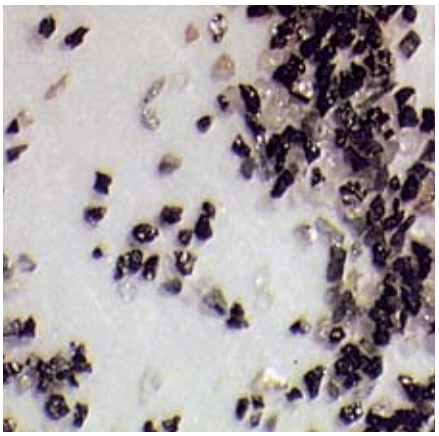
For example granite, a typical crystalline granular rock, will be fragmented into the minerals quartz, feldspar and mica, which can be readily separated into pure mineral fractions.

Quartz



Mica

Application Zircon

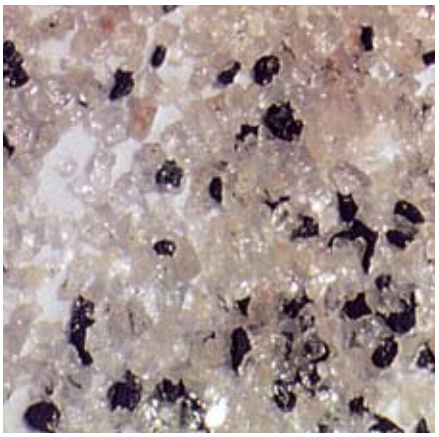


Density fraction 3.3 – 4.2. Good separation of the main constituents hornblende, tremolite and apatite (mean grain size 100 µm)

Selective fragmentation of an even- and medium grained, slightly foliated tonalite with zircon.

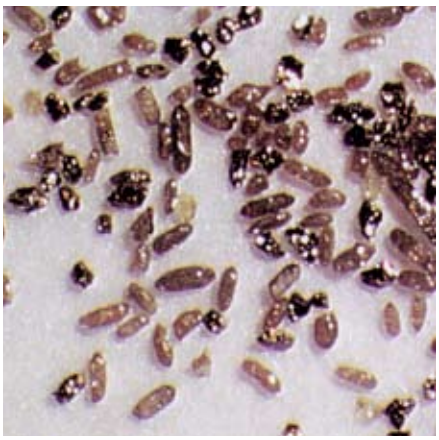
After processing 1.5 kg sample for only 5 minutes the tonalite sample was fragmented to below 750 µm and selectively separated into mono-mineral fragments. The yield of zircon crystals was approx. 150 mg. The liberated zircon crystals are virtually unbroken and the surfaces are very clean. In contrast to mechanically crushed samples, no remnants of other minerals such as biotite have been found on the zircon surfaces.

Pictures and analysis: Courtesy of J. Marmo, Geologic Survey of Finland.



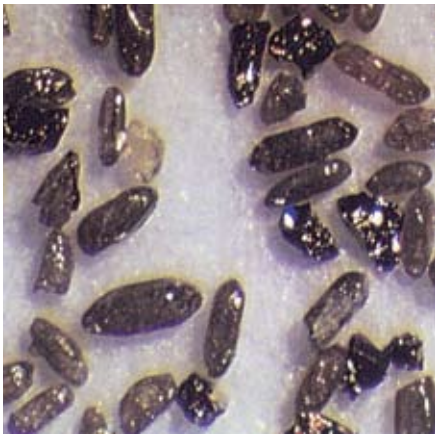
Sieve fraction 120 – 315 µm.

Good separation of light (quartz and plagioclase) and dark (biotite and hornblende) minerals (mean grain size 250 µm)



Density fraction +4.2.

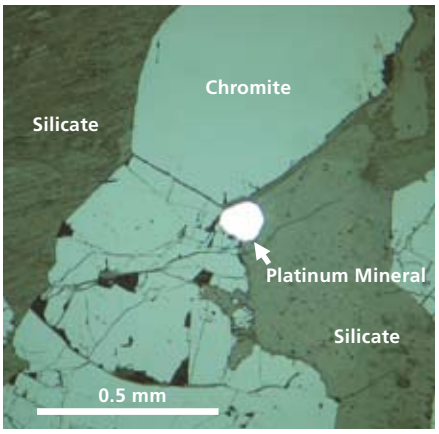
Good separation of the main constituents zircon, pyrite and monazite (mean grain size 100 µm)



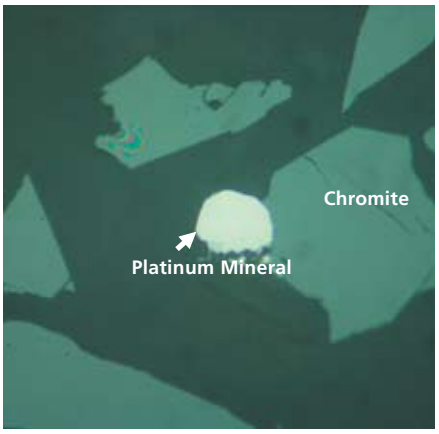
Close-up of picture above. Note the clean surfaces of the zircon crystals.

Applications

Application Chromite Ore with Platinum Mineral



Chromite ore with platinum mineral inclusions

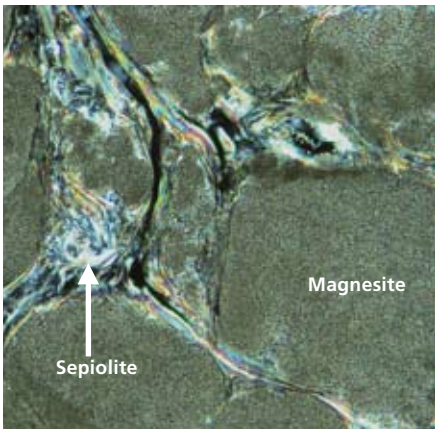


Chromite grains with partially liberated platinum mineral. (Embedded sample, grain size 80-100 µm)

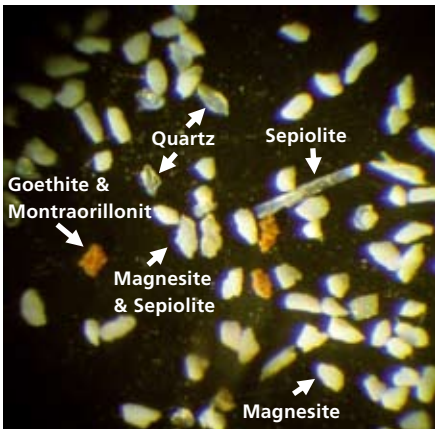
Pictures and analysis:
Courtesy of K. P. Burgath, Federal Institute for Geosciences and Natural Resources of Germany (BGR)

Mechanical comminution of compact chromite deposits produces multi mineral grains and excessive amounts of dust. The recovery of platinum minerals is very difficult. Selective fragmentation, on the other hand, produces only small amounts of fines and no dust. The breakage occurs preferentially along grain boundaries and inclusions, thus liberating the platinum minerals.

Application Magnesite



Magnesite ($MgCO_3$) ore with sepiolite intergrowth



Liberated mineral fragments of magnesite ore (Size fraction 100 – 125 µm)

Magnesite deposits with sepiolite intergrowth are of minor quality because the separation of sepiolite from magnesite by classical methods is very difficult or very often not possible. Selective fragmentation makes the separation of sepiolite and magnesite possible. After processing a sample for only 2 minutes, 50% of the sample was fragmented to below 1 mm and selectively separated into mono-mineral fragments.

Application Waste Incinerator Slag

Iron

Nonferrous heavy metal

Aluminium

Non-magnetic, density < 2 g/ml

Non-magnetic, density 2 – 2.5 g/ml

Non-magnetic, density >3 g/ml

Liberating the individual components
Municipal waste incinerator slag (bottom ash) contains different types of organic, mineral and metallic components which are fused together in hard slag agglomerates. In order to determine the material composition, the individual components of the slag agglomerates need to be separated.

selFrag-Lab offers the possibility of liberating the individual components without needing to grind the slag to a fine powder.

By means of classification, density sorting and magnetic separation, clean components can be isolated for quantification and further analysis.

Applications

Application Concrete

Recovered sand, 0.5 – 1 mm

Recovered sand, 1 – 2 mm

Recovered gravel, 2 – 4 mm

Recovered gravel, 4 –8 mm

Recovered gravel, 8 – 16 mm

Recovered gravel, 16 – 32 mm

By means of selective fragmentation, mineral composite materials can be separated along grain boundaries.

For example, concrete is readily separated into cement paste and sand and gravel aggregates of high quality.

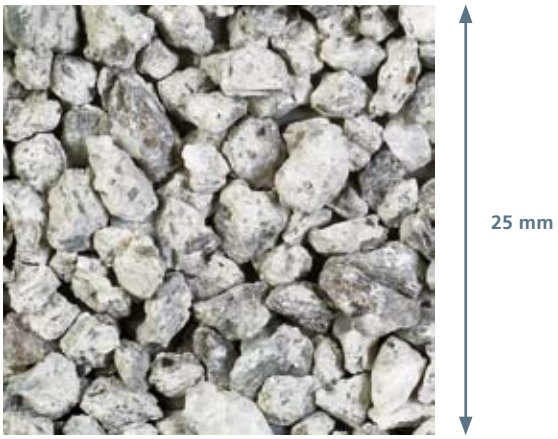
Application Steel Fiber Reinforced Concrete

Drilling core sample

The strength of steel fiber reinforced concrete is a function of steel fiber content. For quality control drilling core samples must be extracted from the hardened concrete and examined for steel fiber content.

selFrag-Lab is ideally suited to selectively fragment concrete into its different parts, i.e. steel fibers, gravel, sand and cement stone. For steel fiber analysis these parts can be completely liberated as whole undamaged fibers without undue grinding of the concrete. With a magnet they can be easily separated and quantified.

To liberate 100% of the steel fibers from concrete the fragmentation of a 2 kg sample can be accomplished in less than 2 minutes.



Concrete

Steel fibers

selFrag-Lab sets new standards in pulsed power sample processing:

- top quality yield
- user friendliness
- compact unit

Specifications selFrag-Lab

Dimensions	Max. L x W x H = 200 x 80 x 200 cm Required spacing around equipment: min. 100 cm on each side
Electric power	3-Phase, 12 kVA, 400V (other voltage on demand)
Weight	1700 kg
Construction	Stand-alone enclosed equipment.
Sample volume	Approx. 1 dm³ pre-crushed solids. Inserts for small quantities available (smallest vol. 0.25 dm³). Largest single piece approx. 5 x 5 x 5 cm
Moving parts	Electrically driven lifting table for positioning of process vessel
Control	Graphic touch panel (English or German, other languages on demand)
Gas circulation	Nitrogen (technical grade)
Water requirement	Approx. 5 liters per sample

Available Options:

- Dedicated process vessel with different volumes, e.g. for small quantities or specially shaped samples
- Various interchangeable sieve bottoms
- Interchangeable HV-working electrodes in various materials
- Auxiliary cart for handling of process vessel
- Support frame for easy manipulation of the process vessel
- Fully equipped sink with support frame and integrated solids retaining basin for easy handling and cleaning of the process vessel.



Our Services

Individual service packages can be selected according to the customer's needs.

- **Financing**
  - Various financing models
- **Basic Services**
  - Shipment, installation and start-up
- **Training**
  - Operating and safety orientation
  - Training of staff
- **Service and Maintenance**
  - Ammann runs a 24 / 7 service department
  - Maintenance and spare parts on an as-needed basis
  - Comprehensive service level agreements (SLA)
- **Process and Business Support**
  - Performing of fragmentation tests for special applications
  - Consulting

Ammann Schweiz AG
Eisenbahnstrasse 25
CH-4901 Langenthal
Tel. +41 62 916 61 61
Fax +41 62 916 64 02

www.ammann-group.com

February 2006