Ceramics Keramik Céramique

S I L I P L A S T
H S

for the injection moulding of silicate ceramics

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Introduction

The injection moulding of ceramic powder allows an almost **completely automated production of complex geometries in large numbers** without any considerable finishing requirement.

Time-consuming production steps, that can generally only be carried out manually, e.g. the attachment of handles during the manufacture of porcelain cups, are no longer necessary.

The addition of an injection moulding binder brings the ceramic powder into the state where it flows under the influence of temperature and pressure, which is necessary for moulding with conventional plastic injection moulding machines.

The feedstock (powder-binder mixture) is produced by intensive homogenization of the powder with the binder. The preparation equipment available for this purpose, e.g. shear roll or twin screw extruders, produces homogeneous mixtures while at the same time breaking down powder agglomerates. The aim is to coat the individual powder particles as completely as possible in order to guarantee optimal flow properties during moulding and to achieve an even shrinkage of the moulded body during the later firing. After the mixing process the feedstock is granulated to ensure good feed times and, hence, constant dosage times during pressure moulding.

After moulding the green product is bonded as a result of the cooling and solidification of the injection moulding binder and possesses adequate strength for the following process steps (e.g. transport to the debinding and/or sintering unit).

The debinding of injection moulded components is carried out by extraction with water.
This process removes up to 65 % of the binder used. The binder remaining guarantees the adequate strength necessary for transport to the sintering unit. The residual binder is removed from the component by pyrolysis during the process of sintering. The channels that are opened up by the previous debinding allow the residual binder to escape without damage to the microstructure of the component.

Fields of application

Ceramic raw materials are basically divided into silicate and nonsilicate (oxide and nonoxide) classes.

The differing qualities of ceramic raw materials demand carefully selected injection moulding binder properties for each application.

SILIPLAST HS is an injection moulding binder which has been specifically designed to meet the requirements of silicate ceramic raw materials.

The amount of injection moulding binder that requires to be added depends on the composition of the body and the particle size distribution of the powder and is generally approx. 20 to 22 percent by weight for porcelain ($d_{90} \leq 44$ µ).

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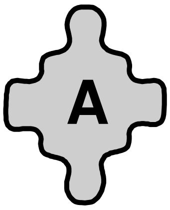
Product structure

An injection moulding binder must meet many different requirements for optimal processing and production of products of good quality.

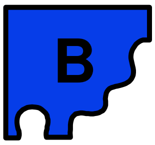
The complex requirement profile is characterized by optimal plastification and wetting properties of the binder, good flow and mould-filling properties of the feedstock and good release properties of the green product from the mould with adequate green strength and rapid removal of the binder before firing without damage to the microstructure.

The good thermal stability of the binder in the processing range means that there is a wide processing window with respect to changes in temperature and pressure during production. The toxicological safety of the substances released in debinding is also another important requirement.

In order to meet these requirements the **SILIPLAST** binders are made up of varying quantities of different functional components. These are so harmonized with each other with respect to their chemical structures and physical properties that they display their effects during the individual process steps, such as preparation, moulding, debinding and firing.

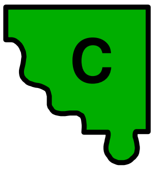


Component A as the major component (base) of the injection moulding binder acts as plasticizer for the powder. The characteristic property of this component is its **water-solubility**, so that the debinding of injection moulded products containing **SILIPLAST HS** can be carried out exclusively in the waterbath.



Group B is composed of several **water-insoluble** components B1, B2, B3, ... These also have, alongside their function as **plasticizers,** the function of providing adequate **dimensional stability** to the injection moulded objects **after extraction** of the water-soluble component A.

The individual components of group B differ basically in their physical properties, e.g. melting point, viscosity and hardness. The composition of these components depends on the technological parameters for the particular application.



Component C takes on the function of the **lubricant**. Its use minimizes the friction between feedstock and metallic contact surfaces during preparation and moulding.

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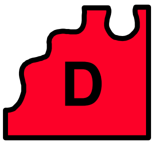
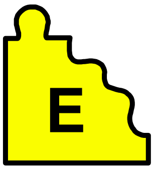


Component D acts in **SILIPLAST HS** as a **wetting agent**. Wetting agents act directly at the contact points between the surface of the powder particles and binder and, thus, fulfil a further important function.

Only a wetting agent specifically chosen for the particular application can maintain adequate feedstock homogeneity during preparation. In addition the wetting agent allows the reduction to a minimum of the amount of binder that needs to be added for injection moulding.



A further important functional component is represented by **Component E** which acts as **release agent** on removal of the injection-moulded component from the mould. This avoids structural damage to the component caused by adhesion to the mould.

The components employed in the **SILIPLAST HS** system include synthetic and native raw materials. The common characteristics of all the raw materials used are their environmentally friendly nature and ready availability.

The problem-free handling of the eluate after debinding and the toxicological safety of the decomposition products released on pyrolysis of the residual binder during firing make continuos production possible with **SILIPLAST HS.**

The following is a selection of specific characteristic product data for **SILIPLAST HS**:

Appearance	ivory colour
Water solubility [20°C]	approx. 65 %
Density [25°C]	approx. 1,2 g/cm³
Melting point	approx. 112°C
Viscosity [140°C]	approx. 2325 mPa·s [Brookfield Sp2, 12 rpm]
Viscosity [160°C]	approx. 2225 mPa·s
Residue on ignition	max. 0,1 %

Investigations of the thermogravimetric behaviour of the residual injection moulding binder after debinding reveal that the first 20 to 30% of the residual binder escape at $T \leq 380$ °C and the remaining 70 to 80% at $390 \leq T \leq 470$ °C (see **Figure 1**).

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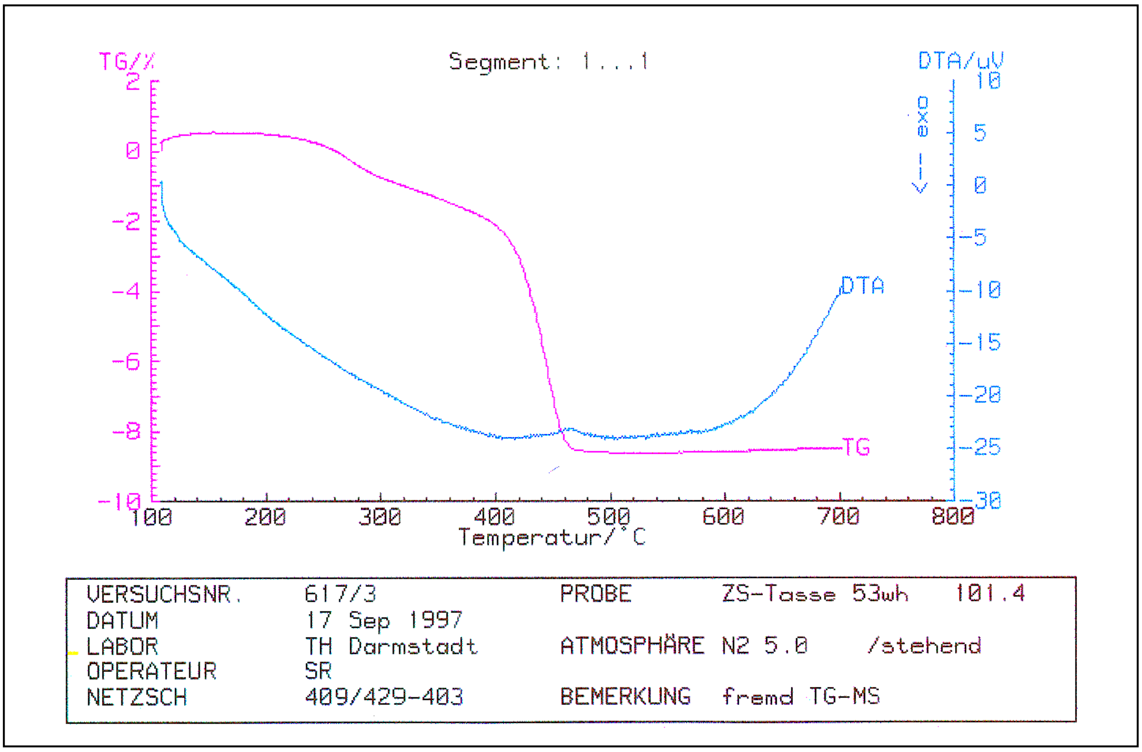

Fig. 1: Thermogravimetric measurement of residual binder

Mass spectrographic investigations carried out in parallel confirm the toxicological safety of the escaping decomposition products (see **Figure 2**).

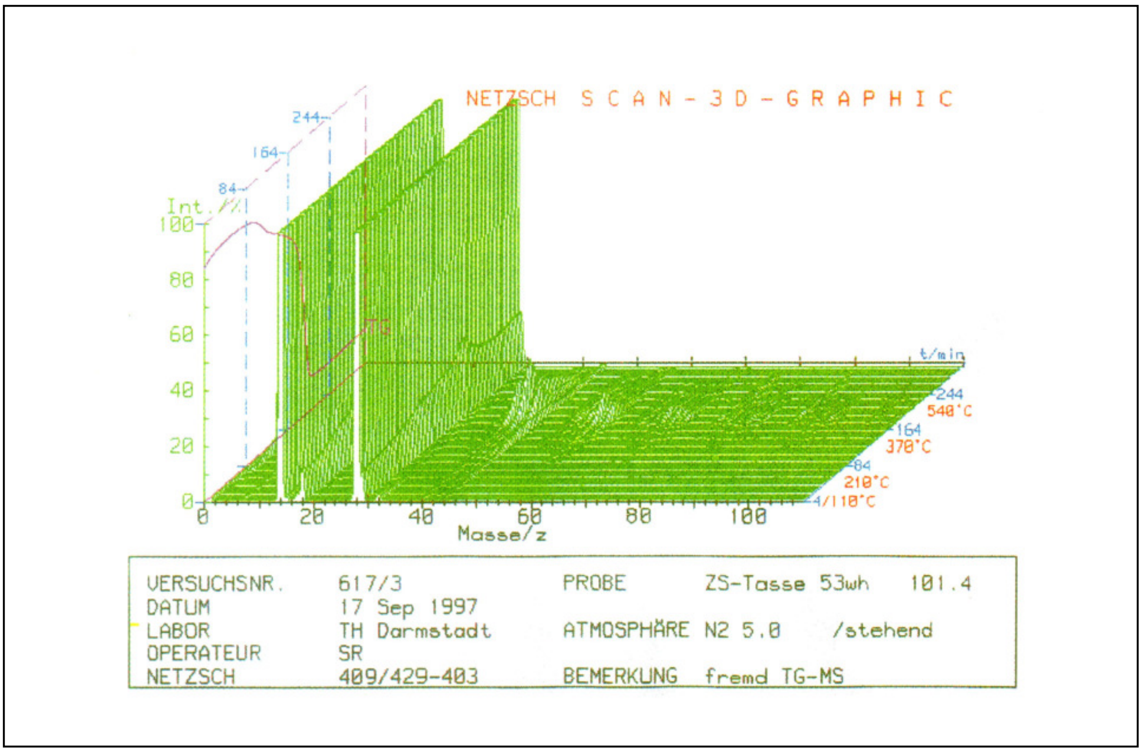

Fig. 2: Mass spectrographic measurement of residual binder

From these investigations it emerges that it is primarily **paraffinic** and **naphthenic decomposition products**, e.g. **alkanes**, that are formed on pyrolysis of the residual binder. **No** nitrogen compounds (e.g. cyanides) or benzene derivatives (e.g. toluene) are released.

Production technology

The preparation of the powder with binder (feedstock production) is a basic technological step in injection moulding production. Intensive mixing of the two components in a suitable plant, such as shear roll or twin screwed extruder, is intended to coat the individual particles of powder as completely as possible with the binder and, thus, to achieve an optimum feedstock homogeneity. Inadequately homogenized feedstock is characterized, for instance, by poor flow and mould filling properties. In addition, the inhomogeneous binder distribution within the component leads to nonsymmetrical shrinkage, which can lead to distortion of the component up to and including its destruction.

The technological properties of the final product and their reproducibility required for a particular application can only be achieved if the condition of optimal homogenization is realized. Faults caused during feedstock preparation continue in the process steps that follow and are reflected in the final product.

1. Preparation

- ① **Homogenization**
- ② **Granulation**

2. Moulding

- ① **Injection moulding machine**
- ② **Removal robot**

3. Transport

- ① **Temperature-regulated waterbath**
- ② **Eluate precipitation**
- ③ **Sediment collection and, if applicable, recycling of the sediment**

4. Drying

5. Sintering

Fig. 3: Production cycle

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Debinding

When **SILIPLAST** injection moulding binder is used a prominent characteristic is the fact that a **single debinding step** exclusively with water is adequate to remove such a high proportion of the injection moulding binder that the sinter firing can be carried out directly after a brief period of drying. This very gentle, environmentally friendly and fuel cost-minimizing variant of the injection moulding process is the result of extensive development work with numerous powder types. To illustrate this the debonding kinetics have been determined for porcelain powder as a function of the waterbath temperature (see **Figure 4**).

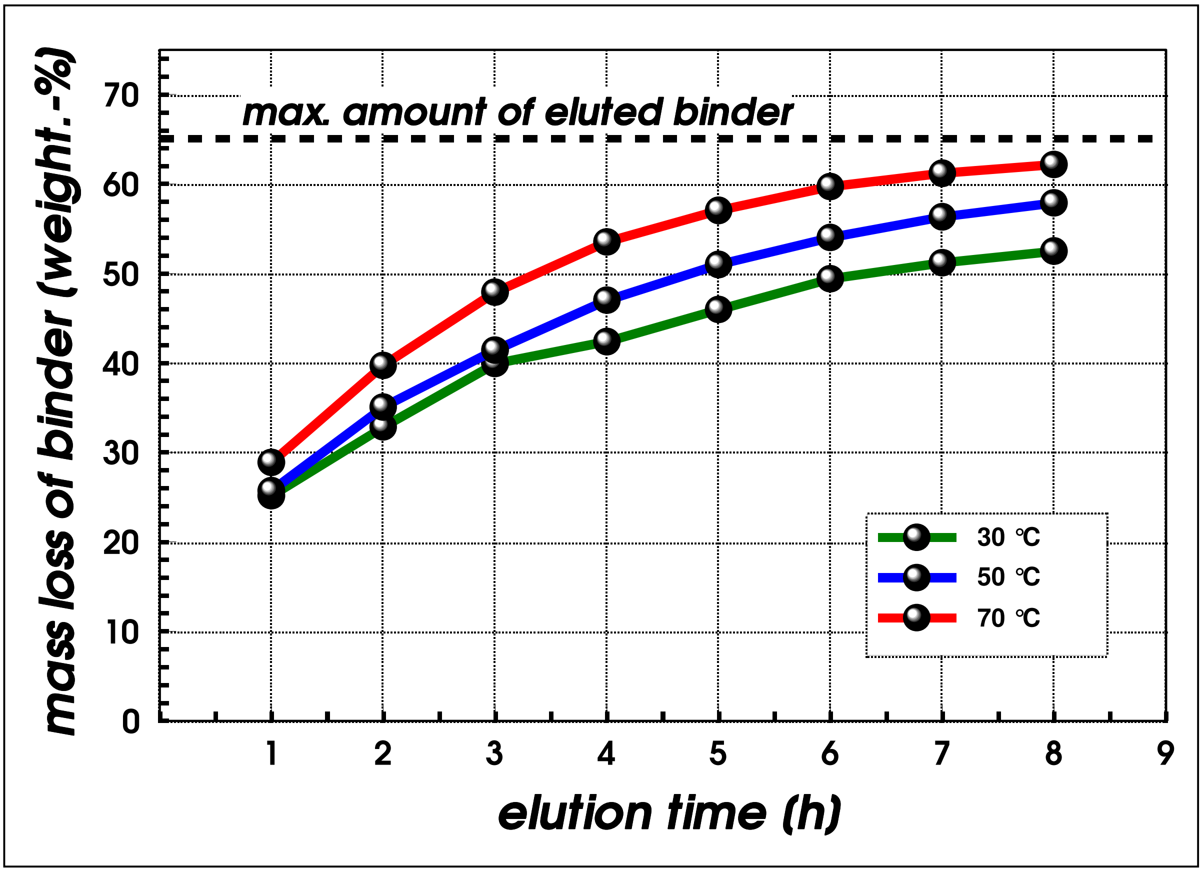

Fig. 4: Debinding kinetics for a wall thickness of 3.5 mm

A further condition is that the up to 65 % by weight of injection moulding binder extracted from the ceramic product can be removed from the process water so that the concept of circulation utilization can be realized. An agent is added to the waterbath which completely binds the eluted binder and forms a precipitate to yield a completely ecologically safe sediment.

It is necessary to dry the ceramic product after its removal from the waterbath. The duration and temperature depend on the geometry of the component.

For the firing that follows a short holding phase at $300 \leq T \leq 400$ °C is recommended in order to drive out the residual amount of injection moulding binder remaining in the casting. Afterwards the product can be subjected to the usual firing conditions.

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Perspectives

The introduction of injection moulding technology for the manufacture of rotationally nonsymmetrical ceramic products, sometimes having very demanding geometries, provides the perspective of being able to realize a completely automated production, functioning to a high standard, and opens unimagined opportunities with respect to design and achievement of reproducibility with respect to product quality. However, to realize this it is necessary that the product steps pass smoothly from one to the next and are adapted to each other.

The modular structure of SILIPLAST HS makes it possible to adapt the processing window to the actual production conditions by varying the individual components.

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