Electric Feedthroughs and Insulating Parts

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This paper reports on aluminia - metal joints, which are used in the electrotechnical field as feedthroughs, pin - type insulators and insulating tubes. The user will receive some references to the choice of suitable materials and to special features concerning the construction of such parts. Some examples demonstrate their variety with regards to widely differing requirements.

1. Introduction

Electrical feedthroughs and insulating parts are an important condition for the operating function of a variety of technical tools and plants. Many varieties of insulating materials are available for the breadth of applications of such construction parts. Figure 1 illustrates the fact that oxide ceramic materials represent only a relatively small segment of this spectrum. They will usually be applied only when there is a demand for properties which are not provided by other, cheaper materials. One example is the need for a high level of electric resistance and mechanical strength for temperatures above 500°C with a simultaneous resistance to quick changes in temperature. In such cases, alumina is usually the only suitable insulating material. Apart from very few exceptions, it is vital for the use of products that the ceramic is joined flush and vacuum tight with metal parts. There are various joining techniques today to achieve this and these are introduced below.

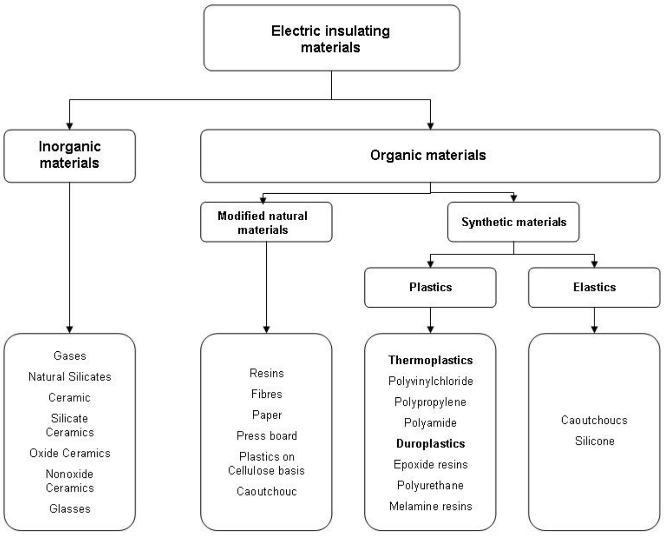

Figure 1: Insulating materials

2. Joining Techniques

Figure 2 shows an overview of standard joining techniques used today for ceramic - metal and ceramic - ceramic joints. The MoMn procedure which is mostly used for flush and vacuum tight joints of these materials is based on research which goes back to the first half of the last century (2, 3, 4). Active brazing has recently become more possible due to the availability of suitable brazes but is used in a comparatively limited way.
Both joining techniques are summarized in Figure 3.

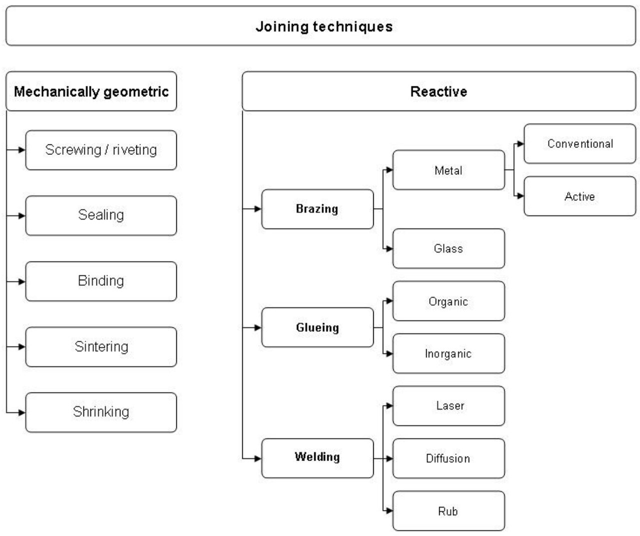

Figure 2: Joining techniques

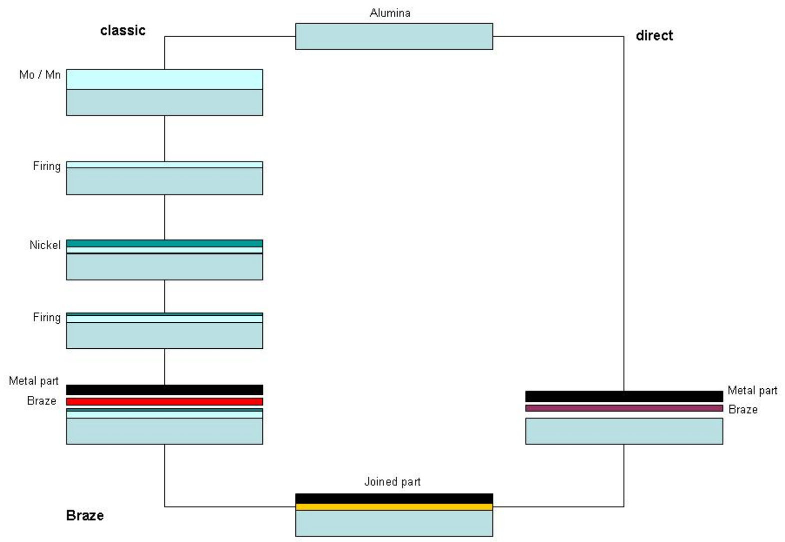

Figure 3: Joining techniques for conventional and active brazing of Al_2O_3 ceramic to metal

Brazing MoMn-metallized Ceramic

The MoMn-procedure is based on a suspension of the pulverized inorganic components in an organic ink system. This suspension is applied to the surface of the ceramic and a metallizing layer is created by a firing process which clings tightly to the surface (5, 6).
As the majority of the standard vacuum brazes does not wet the metallization it is plated by 2 – 5 µm thick Nickel using galvanic or chemical procedures. The ceramic, once it has been prepared in this way, is then bazed to the appropriate metal parts in a reducing atmosphere or in a sufficiently high vacuum. Silver copper eutectic alloy is used as standard material.
Figure 5 shows a cross-section of the joined area of the compound 99.7%Al_2O_3-Ceramic/AgCu28/Mo.

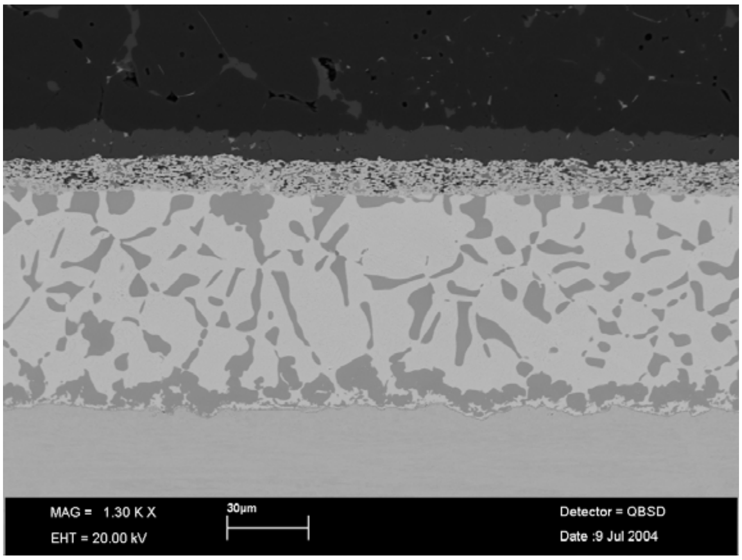

Figure 4: Cross section of metallized and brazed Al_2O_3 ceramic

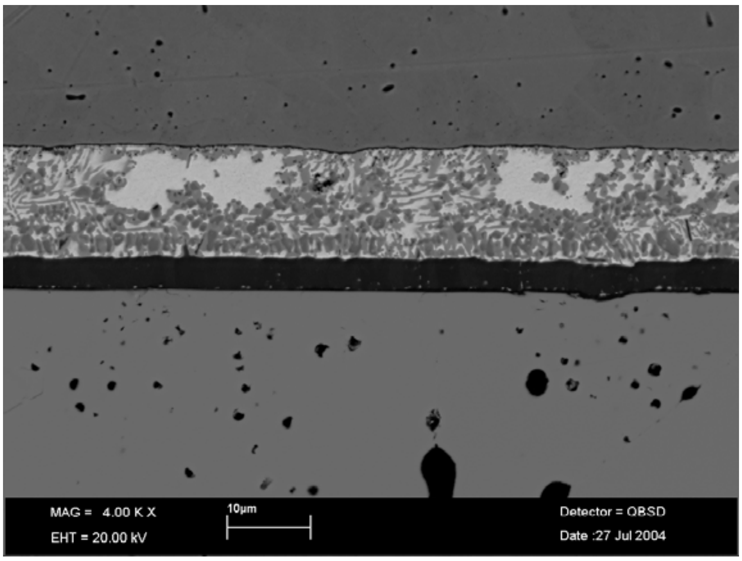

Figure 5: Cross-section of active brazed ZrO_2 ceramic

This combination of materials achieves strength values of more than 200 MPa during tensile tests according to (8) at room temperature.
With increased demands on application temperature, corrosion features and where metals are used which are not wetted by this braze, brazes with increased melting properties are used. Table 1 gives an overview (7).

Table 1: Vacuum brazes – selection

Braze Material	Interval (°C)
Ag Cu 28	780
Ag Cu 26,6 Pd 5	807 – 810
Ag Cu 21 Pd 25	910 – 950
Au Ni 18	950
Cu Ge 10	900 – 1000
Au Cu 65	1000 - 1020

Direct Brazing

This procedure is based on the use of brazes with a low metal content, e.g. Ti, Zr, Hf. They wet Al_2O_3 which means that there is no need for prior metallization. The strength values of active brazed Al_2O_3-ceramic/Ni42-compounds achieve values of brazed and metallized compounds (9, 10). Figure 4b gives a further example of the joining area of a ZrO_2 ceramic and steel joint brazed by AgCu26, 5Ti3.
However, while active brazing is an attractive option for technical and economic reasons, it has to be said that when it is used especially on feedthroughs, the braze does not flow into the braze gap but remains in the braze depot. If this peculiarity is considered in certain constructions there are ways around this restriction.

3. Choice of Materials and Construction

According to (11) approx 70% of variable manufacturing costs arise during construction. This value originates from the automobile industry and may be transferred to electric feedthroughs and insulating parts only with certain provisos; however it proves that responsibility to provide the customer with a product which is meeting his or her expectations lies in the construction process, while at the same time making sure the product is manufactured at a competitive price. This means:

a) Realization of the required features using simple solutions and standardized starting products
b) construction adapted to ceramics
c) streamlined construction.

The choice of suitable ceramic and metal materials initially requires thorough knowledge of application conditions. Table 2 gives an overview over central requirements in the three joining areas ceramic, joining area and metal.
Designing the joining construction takes place in line with the geometric indications by the user and the thermal suitability of the chosen materials (Figure 5).

Table 2: Central requirements

Properties	Focus on: **Ceramic**	**Joining Zone**	**Metal**
Electric			
Breakdown voltage	+		
Sparkover voltage	+		
Creepage path	+		
Dielectric constants	+		
Resistance	+		
Magnetic			+
Thermal			
Temperature during application		+	
Definition of temperature shock		+	
Mechanic			
Strength		+	
Geometric			
Size tolerance			+
Surface roughness	+		
Leak rate: Helium		+	

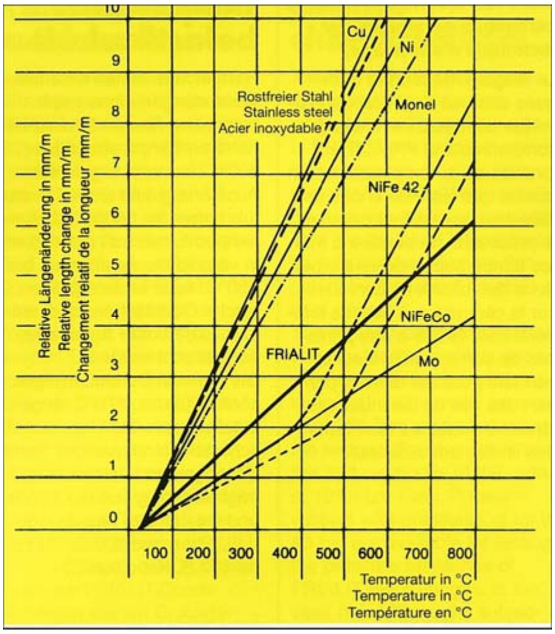

Figure 6: Thermal expansion of metals compared with Al_2O_3 ceramic

Figure 7 shows some basic types of joint constructions which are frequently used for feedthroughs and insulating parts.
Where possible the ceramic metal joint is created in such a way that the metal part, once brazed, exerts compression strain onto the ceramic as ceramic achieves the highest strength values under this type of load.

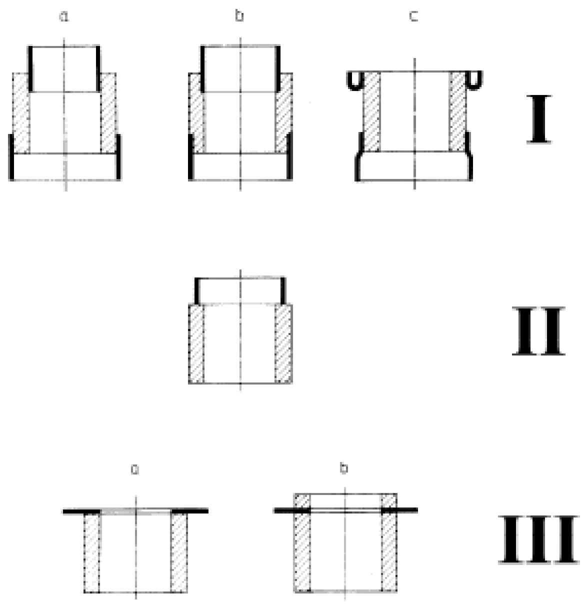

Figure 7: Basic types of joints constructions

The construction type I comes close to the specified target.
In the case of outside circumferential brazing specially adapted metal composite materials (Ni42, NiCo 2918) or metals whose WAK is higher than that of ceramic are the preferred working materials. The adapted composite materials are also suited for inside circumferential brazing, however the thermal expansion coefficient (WAK) of other metals should generally be below that of ceramic. An exception are metals such as copper which can also be used for inside and outside circumferential brazing in spite of their high WAK, as these materials are able to reduce crack inducing tensions in the joining zone due to their ductility.
Not only does radial compression strain occur with outside circumferential brazing but, due to the varying axial shrinking process of ceramic and metal during the cooling process, shearing stress and tensile stress at the outer junction between ceramic and metal. These stresses are generally negligible when adapted composites or ductile metals are used for wall thicknesses of less than 1mm. In order to be able to work even with few ductile metals such as austenistic steel, the wall thickness of metal parts in the brazed area is often reduced to few tenth millimetres. This allows the mechanic elasticity of the metal part to be increased. This measure allows brazing of metal parts with a brazing diameter of around 10mm without damaging the ceramic.
Greater diameters require the introduction of moveable moulded parts. Where these may be magnetic, brazing e.g. a Ni42 flange of type Ic and consecutive welding on of the steel part is sensible.
If outside or inside circumferential brazing is intended at both ends of a pipe, it is usual practice to cut a groove into the ceramic (type 1b). Such a groove causes additional notch

effect, but this may be controlled by the appliance of sufficiently great radii in the area of the grooves especially when using adapted alloys or ductile metals.
The benefit of this construction may be found in the fact that brazing fixtures will be kept to a minimum and it allows for simple installation of individual parts to be brazed. However, additional effort is required for processing ceramic and this may compensate this cost benefit with the increasing size of ceramic construction parts and/or low number of items.
Applicability of construction type I is often limited to brazed diameters smaller than 50 mm when using non adapted metals, as the differences in WAK of ceramic and metal at brazing temperature may result in brazing gaps which may be filled with sufficient braze only at increased cost. For example the brazing gap of two Al_2O_3- Ceramic and copper pipes in axial symmetric alignment already amounts to 0.4 mm with 100 mm brazing diameter and 800°C after the WAK. In such cases construction type II is often used. The same applies for brazing larger metal parts made from austenitic steel via a ductile intermediate copper layer, as this type of construction allows for great mobility of the metal parts on the front area of the ceramic. Figure 7 shows such a construction as an example. This type of construction makes increased demands of the strength properties of the ceramic, as generally only tensile stress occurs in the joining zone. With a view to manufacturing costs, brazing fixtures need to be more elaborate than for type 1 to meet narrow size tolerances. It seems obvious to design the metal parts in such a way that they are centred on the ceramic without further devices but the expense would be prohibitive except for large quantities.

Figure 8: Al_2O_3 ceramic brazed with austenitic steel with copper layer according to Type II

The construction types I and II are not always appropriate as some applications have space restrictions which require a compact construction part. With such requirements flat soldering according to Type III is used. With this construction type the ceramic is stressed mainly with regards to shearing and tension. Especially with this type the joining zone must stand up to maximum loads as the joining area typically lies above that of Type II: such constructions are manufactured using only adapted metal alloys or ductile metals.

Increasing mechanical safety of such a joint is achieved through a construction according to Type IIIb using a ceramic ring which is welded on. This ring forces the metal part to shrink during the cooling process radially and symmetrically and results in reducing the stress in the joining zone.

Figure 10 shows a selection of feed-throughs and insulating parts mostly with several construction types realized in one construction part.

Figure 9: Examples for feedthroughs and insulating parts

4. Application Examples

Electric feed-throughs and insulating parts are used e.g. in the following areas:

Measuring technique and control engineering
- High ohmic feed-throughs for counter tubes, vacuum measuring devices, flame photometers
- Cable end seals for thermoelements and heating conductors
- Pressure tight feed-throughs for flow measurement and filing level indication
- Insulating pipes for plasma coating plants

Plant construction and equipment components
- Insulating pipes and UHV sealing elements for vacuum devices
- High current feedthroughs for furnace construction

Electro technology / electronics
- X-ray tubes and bases for X-ray apparatus
- High current feedthroughs and housing for controlled current supplies
- Multiple feedthroughs for sensors
- Insulating pipes for service transmission tubes and vacuum switches

Institutes
- UHV tight insulating tubes for accelerating plants

Areas of application for more recent developments are:
- Housing for electronic construction elements in the automobile construction industry controlled by production data
- Heating devices for gases and liquids in dentistry
- Housing for X-ray picture amplifiers in medical diagnostics.

5. Literature

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