

Preparation of WC/Ag Contact Materials with Different Homogeneity

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Abstract

Powder metallurgical contact materials are mainly used in high and medium voltage switchgears. They are composite materials that advantageously combine high melting point with good electrical and thermal conductivity. The homogeneity of their microstructure is essential for the physical characteristics and the switching performance of the electrical contacts. The production and materialographic preparation of WC/40Ag samples (40 weight percent Ag) with different homogeneity are discussed. As well the unequal physical properties of the two components WC and Ag as the varying microstructure made preparation more difficult.

1 Introduction

Technical applications often require contradictory material properties. Composite material advantageously combine the physical characteristics of two or more materials.

Electrical contacts in high and medium voltage switchgears must have not only good electrical conductivity but also a high melting point. These requirements can be met successfully by powder metallurgical composite materials.

In the course of carrying out experiments to improve the homogeneity of tungsten carbide silver contact materials, many samples with different microstructures had to be prepared for materialographic inspection.

2 The Microstructure of Powder Metallurgical Contact Materials

The raw materials of powder metallurgy are metal powders and also powders of chemical compounds. The steps of production are mixing, pressing, and sintering (time critical heat treatment below the melting point).

Refractory metals or their carbides and copper or silver are the raw materials of powder metallurgical contact materials. They combine high melting point with good electrical (and therefore also thermal) conductivity in a composite material. For the production of these materials an additional step of repressing or infiltration with the liquid well conducting component is necessary to guarantee full density.

The microstructure of the contact materials has an important influence on physical characteristics and switching performance of the electrical contacts. In general, a fine-grained and homogenous microstructure leads to high erosion resistance, little welding tendency, good electrical and thermal conductivity, and high hardness. Furthermore, the presence of inhomogeneities can cause a reduction of the interruption ability.

The homogeneity of a contact material is defined by the degree of uniformity of the two mixed phases and can be influenced by

- the grain size of the starting powders,
- the used mixing operation, and
- the used production process for consolidation.

The mainly used contact materials for high and medium voltage switchgears are WC/Ag, W/Ag, WC/Cu, W/Cu, and Cu/Cr. Tung-

sten carbide silver is the material of choice for vacuum contactors. These switchgears have compact construction and are maintenance-free, their field of application is the electrical power distribution.

3 Experimental Work

For the materialographic preparation of powder metallurgical contact materials it is important to have knowledge of the used manufacturing process. A short description of sample production is followed by a discussion of sample preparation.

3.1 Sample Production

The starting materials were WC and Ag powders. For the production of samples the press – sinter – infiltration route was used.

To improve the homogeneity of WC/40Ag contact materials (40 weight percent Ag) different treatment techniques for preparation of powder mixture – mixing, ball milling, and planetary ball milling – were investigated. As parameters the milling time and the filling ratio of the milling container were varied.

After preparation of powder mixture the contacts were cold pressed, sintered, and finally infiltrated with liquid Ag to get full density.

In Figure 1 the applied production route with variations in powder processing is schematically shown.

The consolidated samples had cylindrical geometry and were machined to the measurements that are required for the use in vacuum contactors (diameter 25 mm,

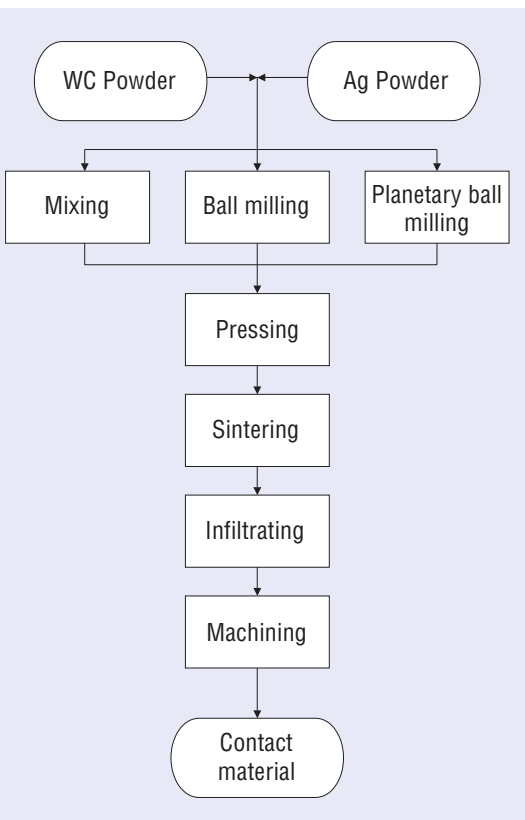


Fig. 1: Principal production route for WC/Ag contact materials showing the variation of powder treatment techniques.

and to obtain a plane and smooth surface. Grinding and polishing of powder metallurgical contact materials with different homogeneity can cause the following difficulties:

- Well-known problems of any materialographic preparation, like the elimination of scratches.
- Difficulties resulting from the unequal physical properties of the two components of the composite material, e.g. smearing of soft over hard material.
- Problems due to the varying homogeneity of the materials, for example the influence of WC agglomerates on pull-outs.

	WC	Ag
Melting point [°C]	>2800	961
Electrical conductivity (20 °C) [MS/m]	2.3	62.9
Thermal conductivity (20 °C) [W/(m K)]	40	419
Density [g/cm³]	15	10.49
Contact hardness [kN/mm²]	2	0.3 - 0.7

Table 1: Physical properties of WC and Ag

in a false microstructure with too few pores and a too optimistic estimation of the electrical conductivity.

As previously mentioned, the used production process and the varying homogeneity of the contact materials had influence on preparation. In Figure 2 to Figure 4 the microstructures of selected sample contacts are shown, representing the optimum result for each mixing respectively milling technique (mixing, ball milling, and planetary ball milling). Using mixing operation both raw materials (WC and Ag powders) have a tendency to form agglomerates during processing due to their small grain size. The energy of the mixer is too low to destroy these agglomerates. The contact material in the con-

height 5 mm). The dimensions of the contacts are important parameters for cutting, which is the first step of sample preparation.

3.2 Sample Preparation

The materialographic preparation should allow examination of the real microstructure of materials. Its main steps are cutting, mounting, grinding, and polishing. In this paper, priority is given to the discussion of possible problems in the course of grinding and polishing. First of all, the samples must be cut to an appropriate size for further preparation. The geometry of the contacts made this step very easy, the samples were cut into two half cylinders.

In general, the cut specimens are difficult to hold securely during grinding and polishing operations, and their shape may not be suitable for observation. To avoid these difficulties the cut contact samples were mounted in a larger mass of material.

Grinding and polishing are very important steps in sample preparation. Their objectives are to remove, as much as is possible, the traces of mechanical damage caused by previous operations

In this connection, it must be mentioned that the electrical conductivity of a contact material strongly depends on the porosity. Therefore, the correct reproduction of pores is very important. The components of the examined composite materials are WC and Ag, Table 1 lists their very different physical properties. Especially the unequal values of hardness can lead to many problems in grinding and polishing. A typical difficulty is smearing of the soft material that can cover not only the hard material but also pores. This may result

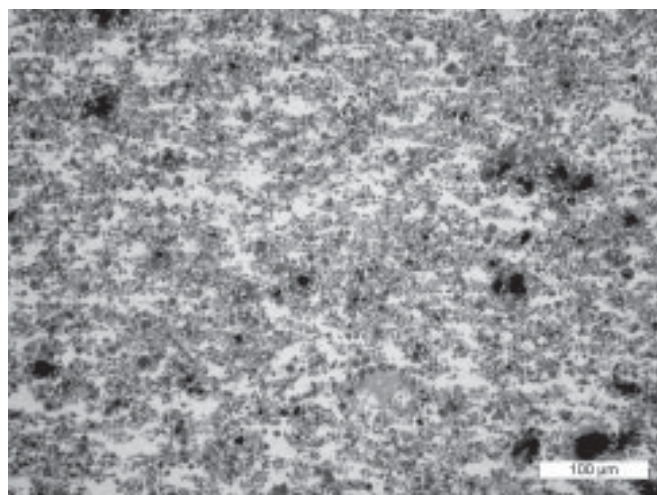


Fig. 2: WC/40Ag contact material produced by mixing. The large dark spots are WC agglomerates and no pores.

Table 2:
Assessment of
homogeneity

	Mixing	Ball milling	Planetary ball milling
Size of WC agglomerates [μm]	<100	<50	<10
Size of Ag clusters [μm]	<150 (partly 200)	<100	<20

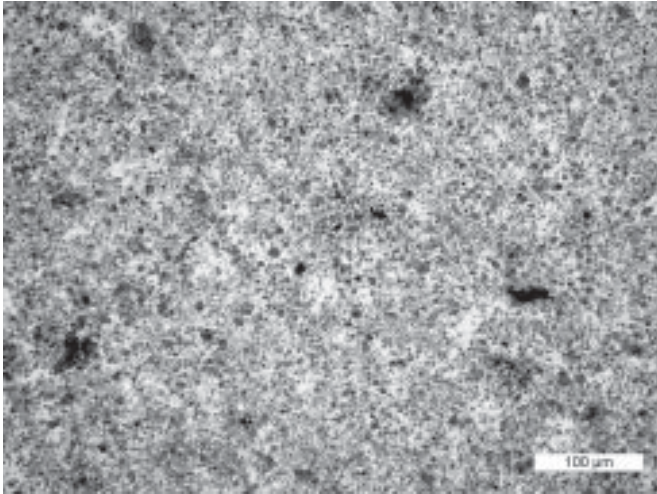


Fig. 3: WC/40Ag contact material produced by ball milling. The large dark spots are WC agglomerates and no pores.

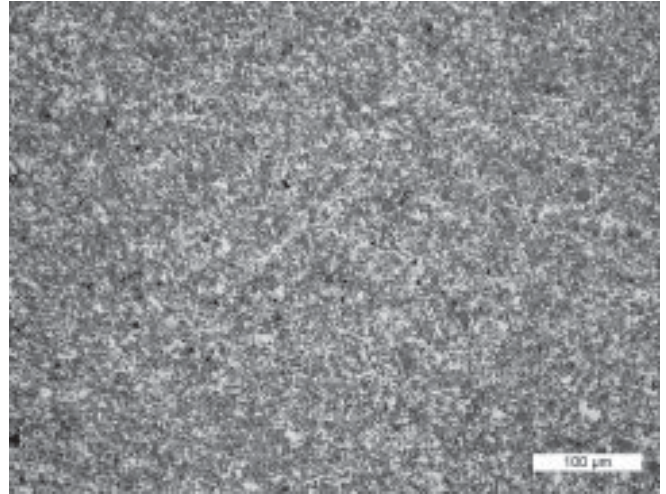


Fig. 4: WC/40Ag contact material produced by planetary ball milling.

solidated state shows an inhomogeneous microstructure with relatively large WC agglomerates and Ag clusters. These inhomogeneities are uniformly distributed over the cross section of the sample contact (Figure 2). Using higher magnification, the dark spots visible on the micrograph could be detected as WC agglomerates. The energy input during ball milling is high enough to reduce the size of the WC agglomerates. The Ag agglomerates can be homogenized, but without reduction of size. On the micrograph an improved homogeneity can be recognized (Figure 3).

With planetary ball milling the WC and Ag agglomerates are destroyed after very short milling time. On the consolidated samples no inhomogeneities are visible and both phases are very well mixed (Figure 4). For assessment of homogeneity the size of WC agglomerates and Ag clusters were determined. The results are summarized in Table 2.

The homogeneity of contact materials influences grinding and pol-

ishing. Pull-outs of WC grains can occur around large WC agglomerates. This may result in a false microstructure with too many pores and a too pessimistic estimation of the electrical conductivity.

4 Summary

WC/Ag contact materials are powder metallurgical composite materials that combine high melting point with good electrical and thermal conductivity. Their raw materials are WC and Ag powders, the steps of production are mixing, pressing, sintering, and in most cases infiltration with liquid Ag. A homogenous microstructure of the used contact material is essential for the physical properties and the switching performance of an electrical contact.

Many WC/40Ag samples (40 weight percent Ag) with different homogeneity were prepared for materialographic examination. Not only the unequal physical characteristics of the two components WC and Ag but also the varying microstructure made grinding and polishing more difficult. In the

course of preparing contact materials, special attention must be given to the correct reproduction of pores because electrical conductivity strongly depends on porosity.

The careful materialographic preparation of electrical contact samples is very important in developing new contact materials for high and medium voltage switchgears.

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