Microstructure, Mechanical Properties and Fracture of Pt -Y_2O_3 Composites

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ABSTRACT

The composite prepared by mechanical alloying of ine Pt powder obtained by waste recovery from linings of glass furnaces with Y_2O_3 dispersed particles (0.5 nass %) has shown better mechanical properties at room temperature as well as at higher temperatures in comparison with those of Pt alloys commercially produced. The qualitative factor, which is known to be a function of starting powders parameters, technology of preparation and compacting operations, shows some correlation particularly with size and space distribution of Y_2O_3 phase in the Pt matrix.

Keywords: Pt-system, Fracture mechanism, Mechanical properties, Qualitative factor

1. INTRODUCTION

The primary application field of platinum alloys is known to be in the glass industry, where their required quality parameters are given by chemical purity, stable properties up to 1773 K, chemical resistance to molten glass, and good formability and weldability /1-4/. The production of Pt alloys from waste has received attention. The related technology is described in detail in refs. /5-8/. Pt fine powder was mechanically alloyed in vacuum with 0.5 mass % of Y_2O_3 particles and compacted by hot isostatic pressing, and then rolled to the final sheet with thickness of 0.6 mm. The aim of this paper is to analyze microstructure, mechanical properties and fractures of Pt-Y_2O_3 composite system.

2. EXPERIMENTAL MATERIAL AND TESTING METHODS

The Pt - 0.5 mass % Y_2O_3 material used in this work was prepared by powder metallurgy. Pt powder obtained from the impure material by chemical processes /5-8/ was applied to the low energy mechanical alloying with Y_2O_3 particles. After reduction and vacuum degassing at 1773 K there followed compaction by hot isostatic pressing (HIP) at 1623 K/175 MPa/3 h and laboratory hot rolling at 1373 K to the final sheet thickness of 0.6 mm. This material was prepared at the Technical University in Vienna in cooperation with the Schott Glaswerke Mainz firm. Specimens for the static tensile tests were investigated in the temperature interval from 293 K to 873 K by using a universal tearing machine of TIRATEST. The microstructure was analyzed by means

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of optical microscopy and transmission electron microscopy (TEM). Fracture micromechanisms were identified by scanning electron microscopy (SEM).

3. RESULTS AND DISCUSSION

Parameters of mechanical properties as well as plastic properties vs. test temperature are depicted in Fig. 1. Strength properties, namely the ultimate yield point $R_p0.2$ and yield point R_m, decrease with increasing test temperature, $R_p0.2$ = 250 MPa, R_m = 275 MPa at 873 K. These values are higher than those of commercially produced Pt alloys /4/. Relatively good plastic properties are found and this is particularly true in the reduction of area. Its value decreases to 45 % at the temperature 873 K.

Microstructure as well as high temperature properties of the material are dependent on the parameters of processing. The grain size, morphology and distribution of Y_2O_3 particles are influenced by the compact condition of the hot isostatic pressing and hot rolling from 20 mm sheet thickness to 0.6 mm. The fine-grained Pt matrix is identified by optical microscopy. Some grains are polyhedric, sized to 2 µm, some are elliptic - elongated, with a length of up to 15 µm and a width of about 2 µm. Such a morphological arrangement is made mainly in the line distribution of Y_2O_3 particles. Recrystallization at low rolling temperatures results in the line distribution of fine grains. These particles suppress the grain boundaries moving in the direction of sheet thickness more intensively than in the rolling direction. There are two size categories of the Y_2O_3 particles: The particles and/or clusters of particles, sized > 1µm, identified on the fracture surfaces at bigger magnifications, and the particles from 20 to 100 nm, identified by TEM as given in Fig. 2.

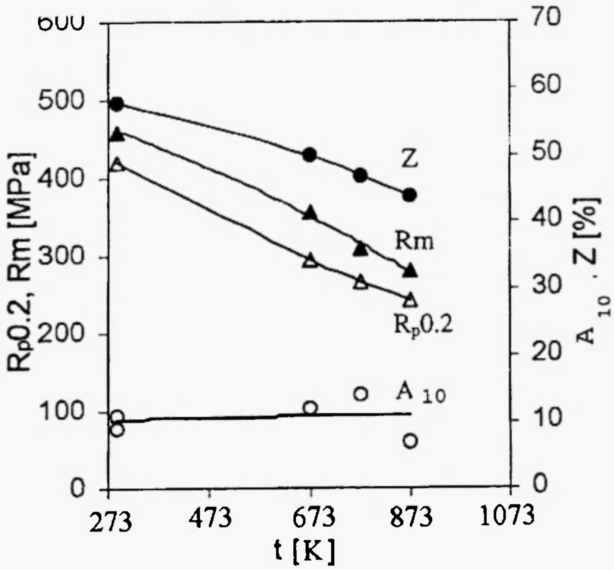

Fig. 1: Strength and plastic properties in dependence on test temperature

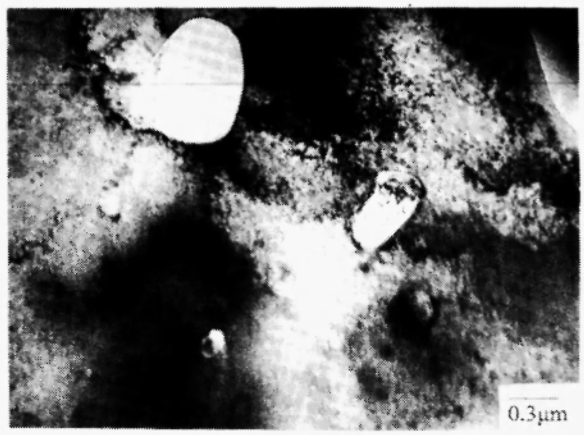

Fig. 2: Size and shape of Y_2O_3 particles

Selective electron diffraction of a particle from Fig. 2 is shown in Fig. 3. The dispersed phase Y_2O_3 is labelled in italics [(002); (511); (513)]; it is a K8 body centered cubic lattice with a lattice parameter a = 1.058

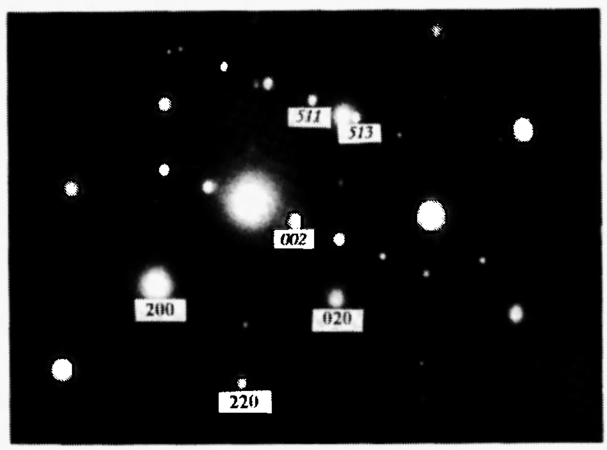

Fig. 3: Selective electron diffraction of the matrix and Y_2O_3 particles

nm. The Pt matrix lattice is face centered cubic K12 with *a* = 0.3912 nm, and labelled in standard font [(200); (020); (220)]. The second phase distribution in the foil surface, as shown in Fig. 4, was estimated by SEM.

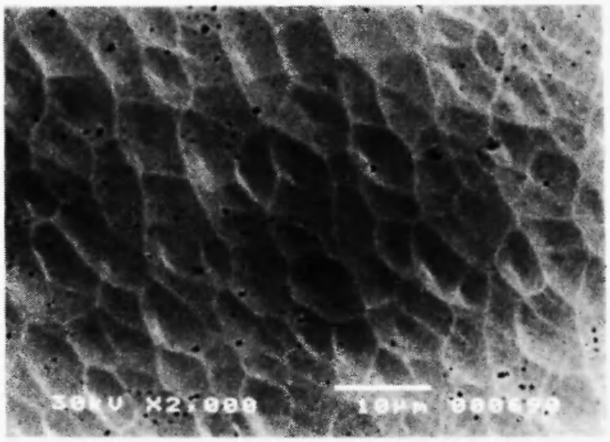

Fig. 4: Foil surface example, used for subgrain size and distribution evaluation by SEM

The fracture surface of the samples fractured at 293 K appears to be fairly smooth, without significant macrodefects or local crack tearing defects (see Fig. 5). The ductile dimples are grouped into two size categories: bigger ones with the diameter from 1 to 5 μm and smaller ones in the range of 0.2 - 0.5 μm. The first group of the dimples is probably initiated by the secondary particles identified using optical microscopy. The smaller dimples are initiated by the particles with the diameter 50 - 100 nm, identified by TEM. These particles are likely to be quite effective for increasing the strength properties. Fine dimples are distributed mainly in failed bridges between particles of the bigger size category. The fracture character of the present material at the temperature 873 K (Fig. 6) refers to shear micromechanism. There are evident some local tearing defects, as exemplified by the results of Fig. 7. The detail may be relevant to the defects induced from change in the fracture micromechanism /9/. The ductile shear fracture was suppressed and the intercrystalline fracture was created; then it was connected with lower plasticity of the material at higher temperatures. The size of the intercrystalline facets is in the range from 1 to 4 μm.

Fig. 5: Ductile dimple character of the fracture at 293 K

According to Jangg *et al.* /10/ for composites prepared by mechanical alloying, a qualitative factor (QF) can be estimated in the following equation on the basis of statistical analysis of an extensive set of values

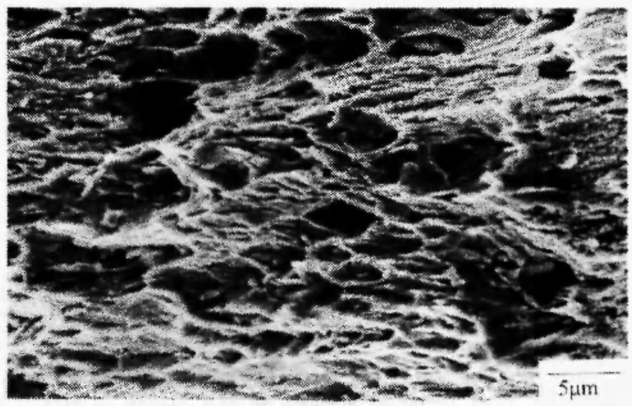

Fig. 6: Shear character of the fracture at 873 K

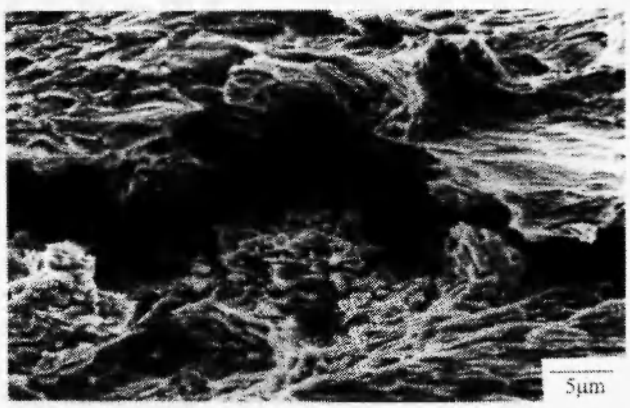

Fig. 7: Detail of the local crack tearing defect of the fracture at 873 K

of mechanical properties:

$$QF = (R_m + 500) \cdot A_{10}^{0.219} / 1420, \quad (1)$$

where R_m and A_{10} are the ultimate tensile strength and the elongation at room temperature, respectively. The qualitative factor for evaluating the final material quality, in the case of preparation via powder metallurgy, depends on a lot of factors such as size, morphology and purity of starting powders, matrix and Y_2O_3 particles as well as preparation methods of composites, compaction and consolidation operations decisive about the particle distribution in the matrix and residual porosity. The qualitative factor also enables us to predict high temperature properties and stability of composite materials /11/. Trends of the QF values for the Pt-Y_2O_3 material in the range from 0.2 to 1.0, determined from the ultimate tensile strength values (R_m) and elongation (A_{10}), can be seen in Fig. 8. Commercially produced materials are labeled by DPH, ZGF and Plativer, whereas Pt-Y_2O_3 is the composite material presently examined. The QF value of the Pt-Y_2O_3 material is only 0.45 owing to the microstructural defects and heterogeneous distribution of the Y_2O_3 phase. The material quality becomes better with increasing QF values at optimal combination of strength and plasticity parameters.

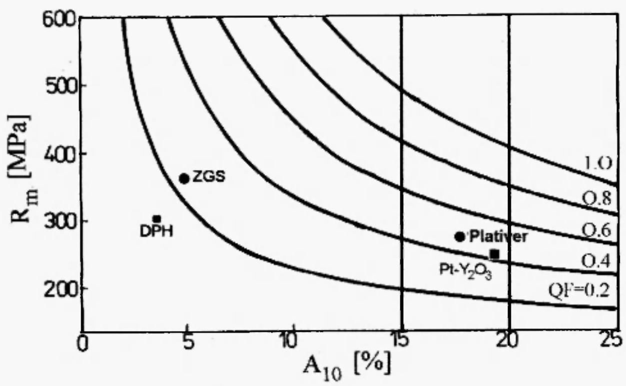

Fig. 8: QF values determined experimentally from R_m and A_{10} and QF values calculated for the respective material

4. CONCLUSIONS

1. Mechanical properties decrease with increasing temperature, namely the ultimate yield point from 415 MPa at 293 K to 250 MPa at 873 K; and the yield point from 465 MPa at 293 K to 275 MPa at 873 K.
2. The fine-grained Pt matrix is identified by light microscopy. Some grains are polyhedric, sized to 2 μm, some are elongated with a length of 15 μm and a width of 2 μm. The Y_2O_3 particles are of two size categories: The particles and/or clusters of particles, sized > 1 μm, identified on the fracture surfaces, and the particles from 20 to 100 nm, identified by transmission electron microscopy.
3. The fracture character at room temperature is classified into transcrystalline ductile, On the other hand, at 873 K the fracture is of intercrystalline shear character.
4. The qualitative factor is a function of starting powders parameters, preparation technologies and compaction operations. The value of QF defined by eq.(1) for the Pt - 0.5 Y_2O_3 composite is found to be 0.45.

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