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Preparation of a dental amalgam alloy from dental amalgam waste

F. DESMET, L. LEMAITRE, A. P. VAN PETEGHEM
Laboratory of Nonferrous Metallurgy, State University of Ghent, Belgium

R. D'HAUWERS
Department of Dentistry, State University of Ghent, Belgium

Amalgam is universally the most used material for dental appliances. It is the result of mixing mercury with a silver–tin alloy. Dental amalgam contains about 50% mercury, 35% silver and 15% tin. Moreover it can contain smaller quantities of other substances such as copper and zinc. Once the mixture has been made, a part of it is used for the restoration. The rest should be considered as dental amalgam waste. Nevertheless these quantities of hardened or hardening amalgam still remain valuable because of their metal content. The recovery of these precious and semi-precious metals has been the aim of a number of investigations. For the recovery of dental amalgam, the extraction of mercury by distillation is the first step. In most of the cases the extraction of the other metals is realized by application of hydrometallurgical techniques [1]. A few years ago a process was developed in which the amalgam waste was transformed into mercury and a dental amalgam alloy, ready for use [2]. In our laboratory, experiments were carried out on the recovery of dental amalgam waste. Similarly to investigations performed in other scientific studies, the extrac-

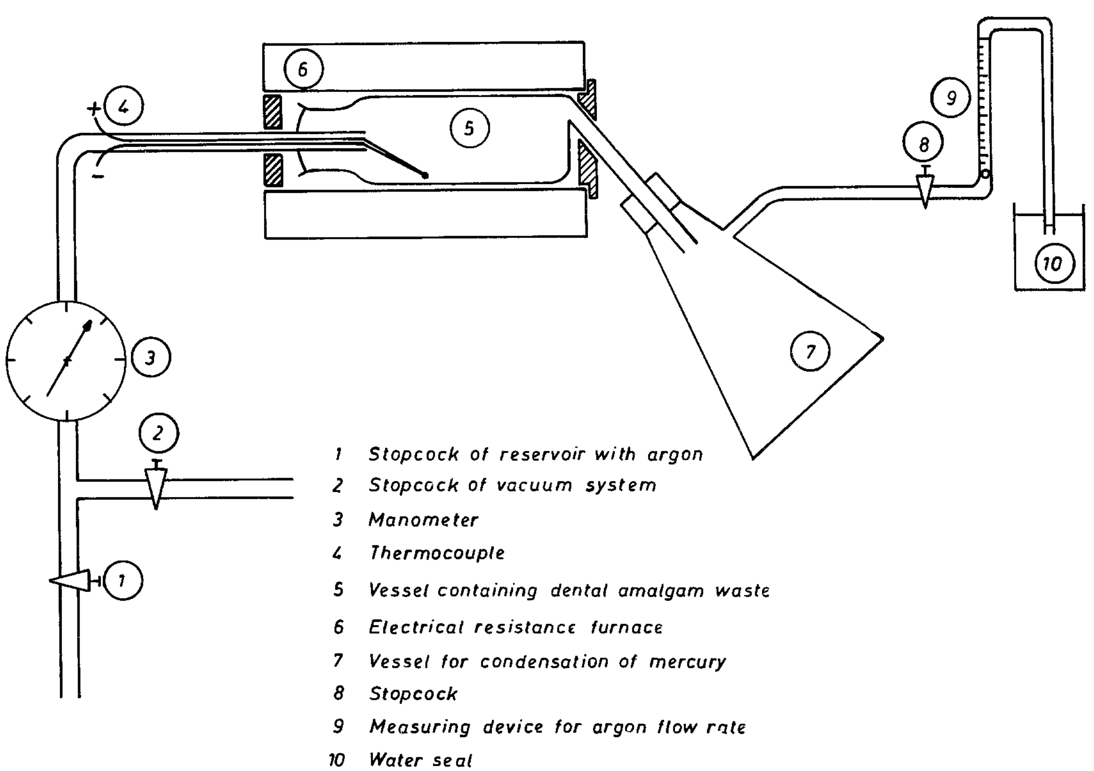

Figure 1 Schematic drawing of the testing equipment for the extraction of mercury.

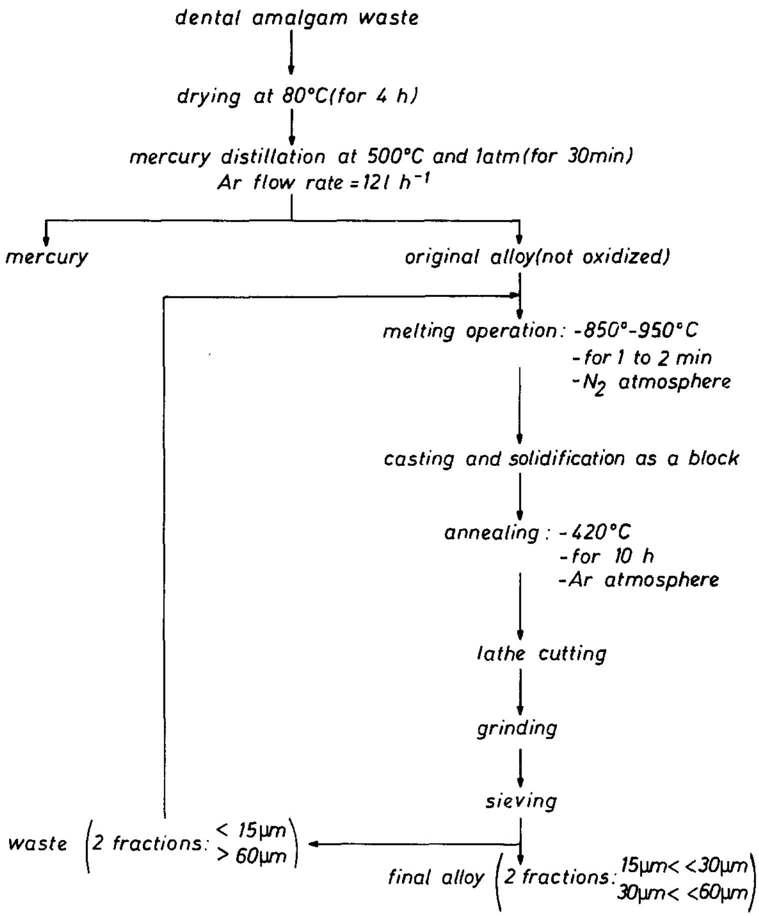

Figure 2 Flow sheet for the process to produce a dental amalgam alloy from dental amalgam waste.

tion of the mercury was to be realized first. The apparatus developed for the evaporation of mercury is shown in Fig. 1. The principal part of the equipment consists of a cylindrical glass vessel containing the samples of dental amalgam waste. Prior to each experiment the sizes of the dental amalgam particles were reduced by a grinding operation. Holding each load for at least half an hour at 500° C was enough for the complete extraction of mercury [3]. Oxidation was avoided by application of a device for argon supply. At the end of each experiment powder remained in the vessel. It had a metallic colour and did not hold any mercury. The vessel was unloaded and the powder was triturated with mercury. The amalgam resulting from this operation did not have the required properties. It could not have any practical use for the dentist since it was hardening extremely fast. As will be explained further on, the powder did not have the suitable metallurgical structure for the production of dental amalgam.

TABLE I

Amalgam	7 day compressive strength (MN m^{-2})
Fluor Alloy	229
Dispersalloy	236
Six Eighty Amalgam Alloy	225
Alloy prepared from dental amalgam waste	178

A number of modifications had to be introduced in the production process before an alloy was obtained ready for trituration with mercury. A first step consisted in heating and melting the powder in an induction furnace. The temperature was held between 850 and 950° C for two minutes at the most. No oxidation could take place because of the supply of nitrogen. Afterwards the liquid alloy was cast and solidification took place in the form of a block. Further steps included the lathe-cutting of the block, the grinding of the particles and the sieving into two fractions: a number of the particles had a size between 15 and 30 μm and others had one between 30 and 60 μm. In order to obtain the optimal characteristics for the dental amalgam, the cast block had to be submitted to

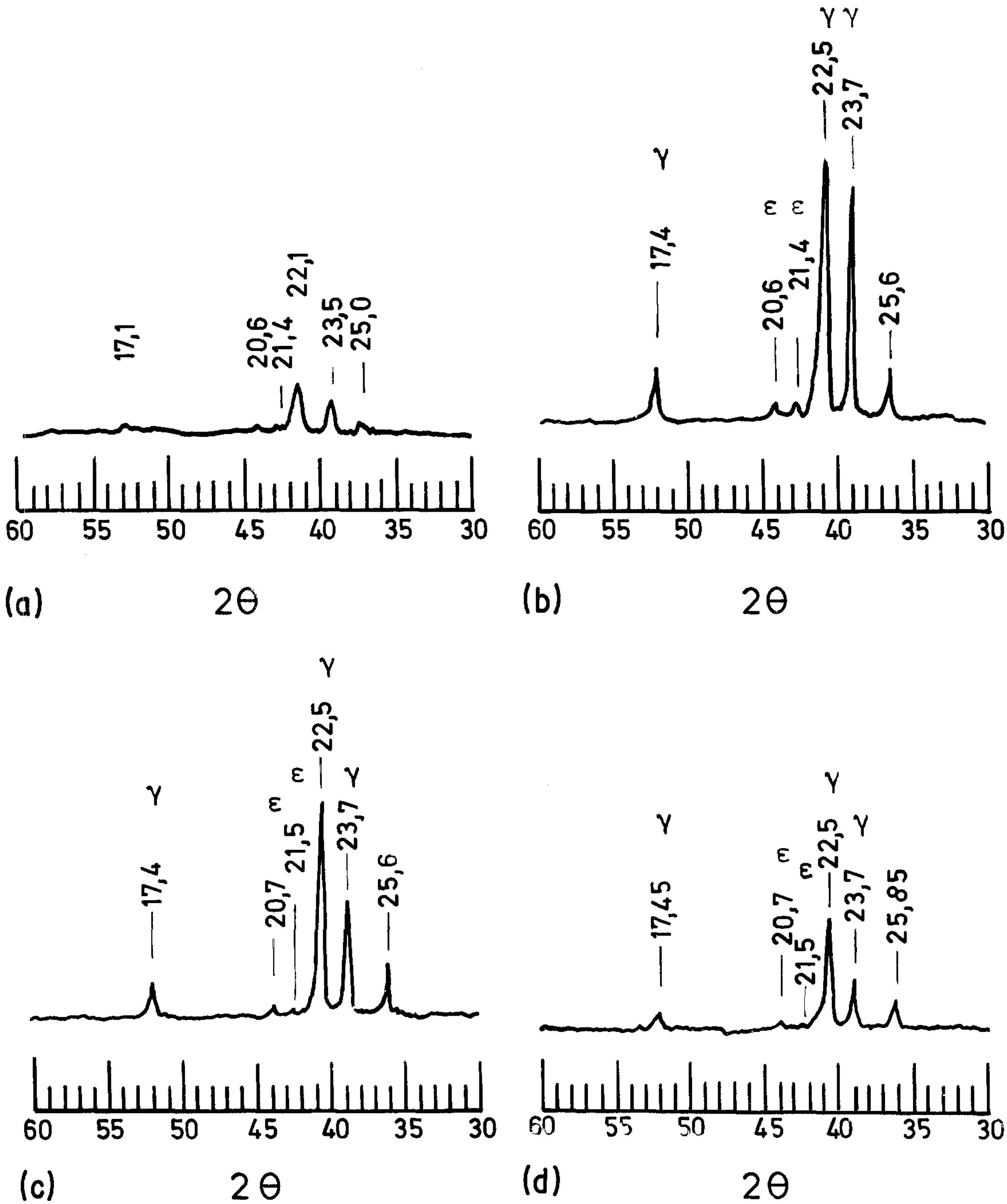

Figure 3 X-ray diffraction patterns (a) the original alloy, (b) the final alloy, (c) Six Eighty Amalgam Alloy, and (d) Framalgame.

an homogenization annealing. It was heated for ten hours at 420° C in the heating device displayed in Fig. 1. The alloy was prevented from oxidation by argon supply. The flow sheet for the entire process is shown in Fig. 2. Mechanical characteristics of dental amalgam made from the original alloy (after mercury distillation) and from the final alloy (after melting, annealing, lathe-cutting, grinding and sieving) were compared to those of several conventional, commercial dental amalgam products. The comparison was made on the base of the compressive strength at low compression rate (0.05 mm min^{-1}) of cylindrical dental amalgam specimens (length = 8 mm; diameter = 4 mm). The results of these tests can be seen in Table I. The mechanical behaviour of the amalgam produced with the alloy prepared in the process described above is comparable with that of commercial dental amalgam products.

The explanation was found by means of an X-ray diffraction analysis. The structural composition of different dental amalgam products was derived from the intensity of the peaks on the X-ray diffraction patterns. In Fig. 3, a comparison is made between four alloys:

(a) the original alloy (after complete mercury extraction)

(b) the final alloy (after melting, annealing, lathe-cutting, grinding and sieving)

(c) Six Eighty Amalgam Alloy produced by Johnson, Matthey and Pauwels (a conventional alloy)

(d) Framalgame produced by Rhône Alpes Mercure (an alloy obtained from recovery).

It was marked on the figure whether the peaks corresponding to the $\gamma(Ag_3Sn)$- and $\epsilon(Cu_3Sn)$-phases could be detected. It is quite clear there is a considerable similarity between the diffraction patterns of Six Eighty Amalgam Alloy, Framalgame and our final alloy. These dental amalgam alloys all contain amounts of γ- and ϵ-phase.

The X-ray diffraction behaviour of our original alloy is totally different. No connection was found between its intensity peaks and those of the γ- and the ϵ-phase. It was impossible to identify them for sure although they seemed to be related to the peaks corresponding to metallic silver. It was claimed that our original alloy contains a high percentage of β-phase, a solid solution of tin in silver.

This could serve as an explanation for the very high rate of hardening of dental amalgam made out of the original alloy.

A general conclusion can be drawn. A process was developed in which dental amalgam waste was transformed into mercury and an alloy. Mixing that alloy with mercury provided an amalgam applicable to restorative dentistry. Further research should be devoted to investigations on the improvement of the mechanical properties.

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