

Development of a roller quenching apparatus for the production of amorphous phases

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Abstract. The details of an apparatus designed to produce amorphous phases by rapid quenching from the melt are described. A drop of molten material is squeezed between two copper rollers rotating against each other at 5000 RPM and a thin foil of the material is produced. The system produces cooling rates of the order of 10^6 K/sec. Details of the development and construction are mentioned.

Keywords. Amorphous phases; quenching; twin rollers.

1. Introduction

Amorphous phases in appreciable quantities are generally produced by rapid quenching from the melt or the vapour. Rapid quenching from the liquid phase is achieved by bringing the molten material into sudden contact with a substrate of high thermal conductivity. This is achieved in practice by (i) the Duwez Gun (Duwez and Willens 1963), (ii) the piston and anvil systems (Pietrokowsky 1963), (iii) the roller quenching apparatus (Chen and Miller 1970) and (iv) the melt spinning technique (Pond *et al* 1969).

Generally the cooling rates produced in the various types of apparatus are about 10^5 – 10^8 K/sec. If the quenching is done by introducing the molten material into a cooled liquid, the cooling rate is about 10^2 K/sec because the gaseous film, formed between the liquid and the material, makes the removal of heat from the sample difficult.

The roller and the piston–anvil systems are twin substrate techniques where heat is removed from both surfaces of the sample, which is produced as a thin foil of 10–100 μm thickness. In the Duwez gun and melt spinning systems only one substrate is used and heat is removed from one side of the foil.

We have developed a roller quenching apparatus for generating cooling rates of the order of 10^5 K/sec. Essentially the apparatus consists of two copper rollers rotating against each other at about 5000 RPM. The molten material is introduced between them and quenched into a thin foil of 50–100 μm thickness. We have produced amorphous phases in the In–Te and Cu–Au–Te systems. These materials have been previously produced by Duwez gun technique (Takayama 1976).

2. Description of apparatus

The basic arrangement consists of two copper rollers, about 5 cm in diameter, which are rotated in opposite directions at about 5000 RPM. The details are shown in figure 1. Both the rollers are mounted on ball bearings capable of rotating at about 10,000 RPM (maximum) under a load of 350 kg (maximum). Since the speed of rotation is very large, very thin oil is used for lubrication. One of the rollers is rotated by a motor and pulley arrangement P. The motor is rated at 1400 RPM and 1/4 HP. By using the pulley and 'V' belt the speed at the roller is increased to 5000 RPM. The bearing mounts M_1 of the roller A are rigidly fixed to a base N. Cross piece C_1 is used to see that the bearings are parallel to each other and there is no strain on the roller. For the same reason the base N has to be machined carefully to be a flat surface. The other roller B is mounted on bearing mounts M_2 , which are allowed to move in a direction perpendicular to the axis of rotation. The cross piece C_2 is used to hold the bearings of roller B parallel. The bearing mounts M_2 are connected mechanically

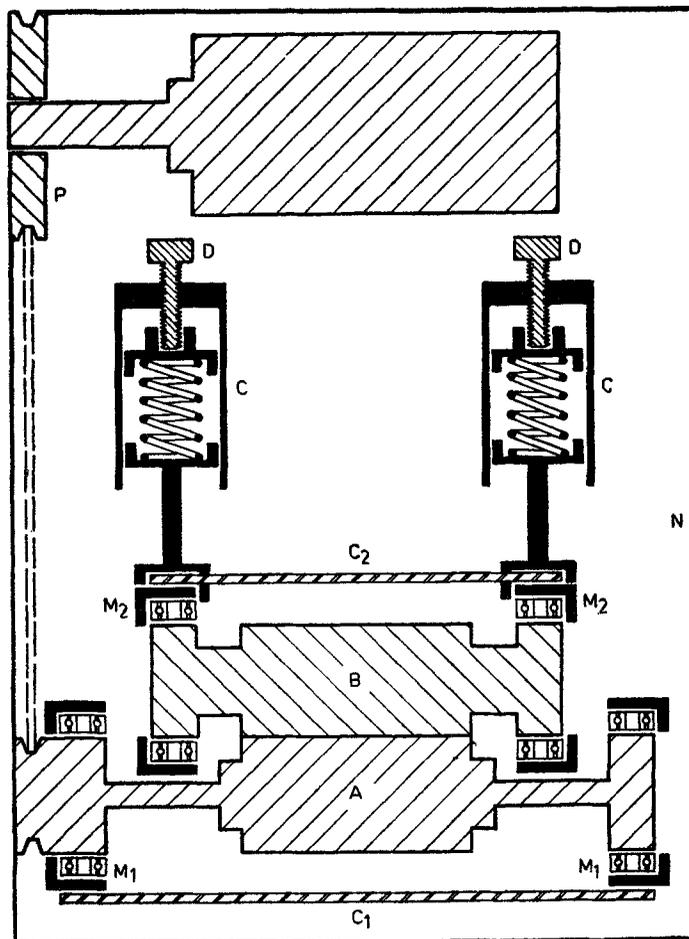


Figure 1. Schematic of rollers.

to springs S, housed in cylindrical chambers C which are rigidly fixed to the base N. The springs are about 4 cm in diameter and have a spring constant of 1 mm per 10 kg load. When the bolts D are tightened the roller B and the bearing mounts M_2 move. Using them, roller B can be pressed against roller A with a load of more than 20 kg.

For developing high cooling rates, the molten material is to be rapidly introduced into the rollers so that cooling and oxidation in the atmosphere are avoided. For this the set up shown in figure 2 is used. A furnace F capable of attaining about 1100°C is employed. The furnace is well insulated by an asbestos box A. A graphite crucible C is attached to the end of a stainless steel tube T. The crucible has a 1 mm hole at the other end. There are three springs S at the top. Using them the position of the crucible can be adjusted in the vertical direction as well as in the horizontal plane. The furnace and the crucible arrangement are mounted on a frame so that the crucible can be positioned on top of the rollers. A thermocouple TC is used to determine the temperature and power input to the furnace is varied to change the temperature.

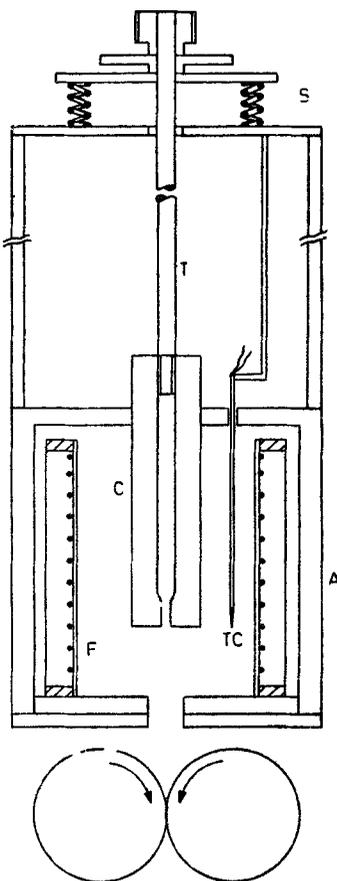


Figure 2. Schematic of furnace and crucible arrangement.

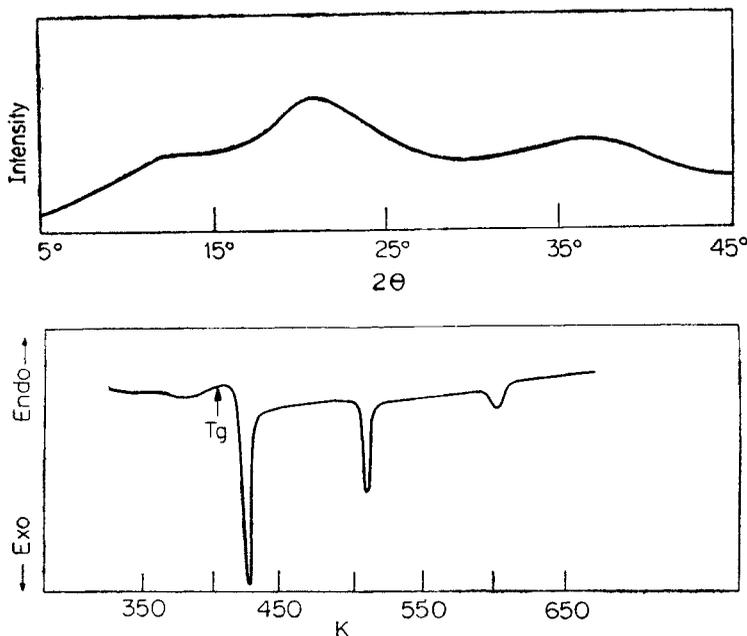


Figure 3. DSC plot and x-ray diffractogram for amorphous $\text{In}_{20}\text{Te}_{80}$ alloy.

3. Experimental Results

$\text{Te}_{70}\text{Cu}_{25}\text{Au}_5$ and $\text{Te}_{80}\text{In}_{20}$ systems are chosen for testing the apparatus. The alloys are prepared by melting them in evacuated quartz ampules. Both the systems are known to form amorphous phases (Takayama 1976). They are hence useful as test systems for the roller quenching apparatus. A small quantity (~ 50 mg) of the alloy is introduced into the crucible after it is heated to the required temperature and positioned above the rollers. A small pressure of argon gas (2–3 Atm) is then used and the molten material comes out of the narrow hole in the crucible and falls between the rotating rollers. The foils produced are collected. X-ray investigations and differential scanning calorimetry are used to confirm that the amorphous phases are formed. The DSC plot, shown in figure 3, clearly shows the endothermic process at the glass transition temperature T_g . X-ray diffractometry shows only two broad maxima and the absence of any peaks corresponding to the crystalline alloy. The fact that amorphous phases could be obtained indicate that the system is working properly. The cooling rate produced can be measured by measuring the interdendritic spacing (Chattopadhyay *et al* 1980). But these are estimates and not accurate measurements. In our system we have not measured the cooling rate. We however note that the alloys $\text{In}_{20}\text{Te}_{80}$ and $\text{Cu}_{25}\text{Au}_5\text{Te}_{70}$ were previously produced in amorphous form by Duwez gun technique. It is universally accepted that the Duwez gun produces cooling rates of the order of 10^6 K/sec. Since we could produce the same alloys with our system we can state that this set-up produces cooling rates of at least 10^5 K/sec.

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References

- Chen H S and Miller C E 1970 *Rev. Sci. Instrum.* **41** 87
Duwez P and Willens R H 1963 *Trans. Met. Soc. AIME* **227** 362
Pietrokowski P 1963 *Rev. Sci. Instrum.* **34** 445
Pond R, Jun and Maddin R 1969 *Trans. Met. Soc. AIME.* **245** 2475
Chattopadhyay K, Ramineni A P and Ramachandra Rao P 1980 *J. Mater. Sci.* **15** 797
Takayama S 1976 *J. Mater. Sci.* **11** 164