

# Evaporation Boats - Properties, Requirements, Handling, and Future Development

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## ABSTRACT

Production and composition of evaporation boats is discussed briefly. The relationship between cold resistivity and resistivity at operating temperature is explained. Basic corrosion mechanism during operation are discussed. Demands placed upon evaporation boat are introduced. Suggestions for further improvement are presented.

## INTRODUCTION

Evaporation boats generally consist of high-melting, corrosion-resistant borides and nitrides, i.e.  $TiB_2$ , BN and sometimes AlN. Important properties of evaporation boats are

- high electrical conductivity
- superior thermal shock resistance
- resistance to molten Aluminum.

An important characteristic of evaporation boats is the cold resistivity which is determined by the ratio of  $TiB_2$  and BN (AlN). The cold resistivity ranges are usually designated by the manufacturers of the metallizer. The resistivity can range from 100  $\mu\Omega$  up to 1500  $\mu\Omega$ .

The main steps of the manufacturing process are shown in the following graph.

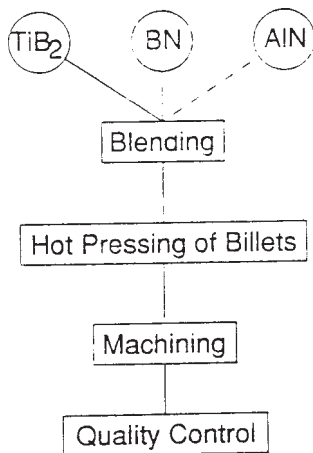


Fig. 1: Process chart

## COLD AND HOT RESISTIVITY

As already mentioned in the introduction, the resistivity is an important characteristic.

The manufacturer of evaporation boat is guided mostly by the required cold resistivity. The metallizer however uses the boats under hot resistivity conditions. For the boat producer therefore it is important to know the relationship between hot and cold resistivity.

The measurements were taken on hot pressed samples in a vacuum chamber at vacuum levels about  $10^{-4}$  mbar. The samples were heated up by direct current. The measuring method is shown schematically in the next picture.

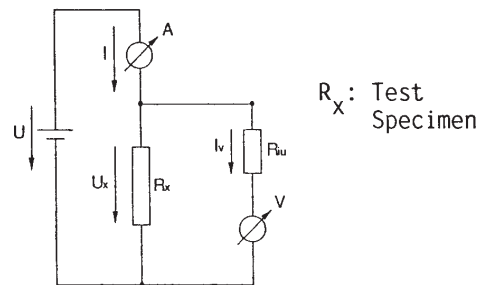


Fig. 2: Measurement circuit

Relationships crucial for the application are shown in the following graphs.

### 1. Measurement of $TiB_2$

$TiB_2$  is the electrically conductive constituent of evaporation boats. Therefore one can expect the relationship between hot and cold resistivity of evaporation boats to be the same as that of pure  $TiB_2$ .

Various grades of hot pressed  $TiB_2$  powders were used as a basis for comparative measurements.

### Result

The curves show an almost identical progression.

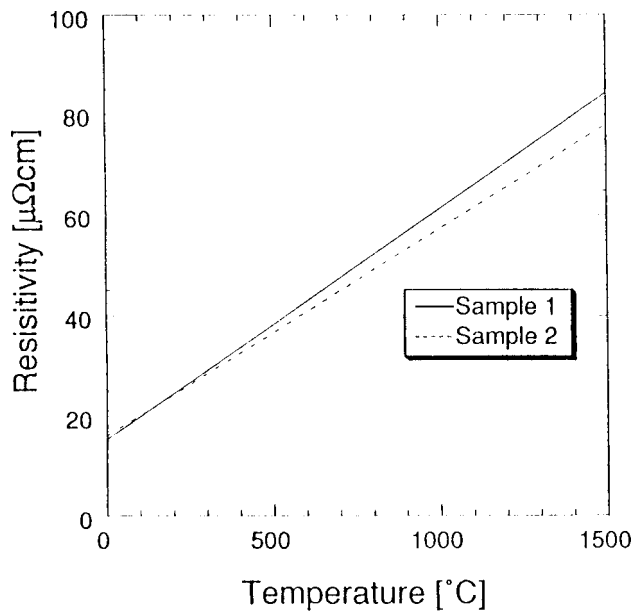


Fig. 3: Resistivity of hot pressed TiB<sub>2</sub> vs temperature

Deviations are due to variations in powders. The ratio of hot to cold resistivity is about 5 (RT→1500°C).

## 2. Measurements with Evaporation Boats

Measurements were taken with 3 types of boats.

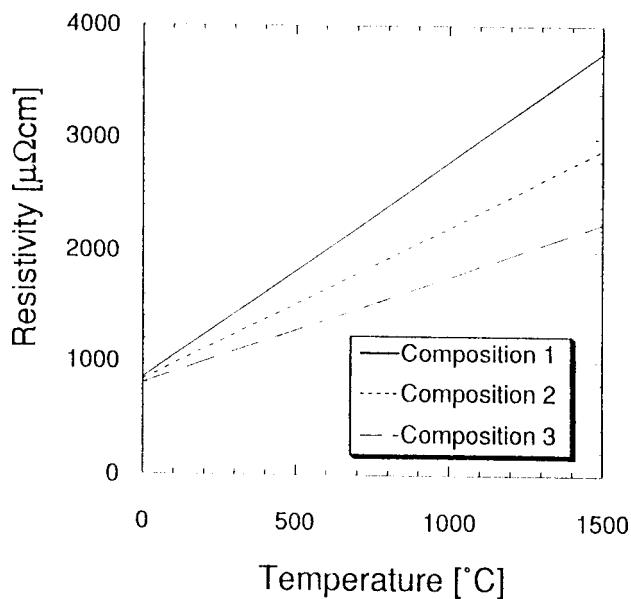


Fig. 4: Resistivity of various boat compositions vs temperature

The examination of various boat compositions reveals that even though the cold resistivities are almost identical, the hot resistivities show larger differences.

Furthermore it becomes evident that the coefficient of the electrical resistivity ( $\alpha$ ) is not identical for TiB<sub>2</sub> and the various boat compositions.

It is important to know - as our investigations show - that the cold resistivity alone is not sufficient for predicting the hot resistivity properties at working temperature. The chemical composition and the structural properties of conductive and non-conductive phase need to be taken into account as well.

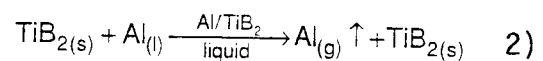
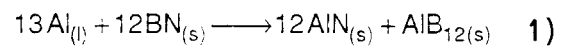
It becomes also evident that the regulation and “handling” of boats have to be adapted to each boat type and that they are different for boats from different boat manufacturers.

## CORROSION MECHANISM

During operation of ceramic evaporation boats deposits develop from contact with molten aluminum.

These deposits increase with increasing operation time and therefore are detrimental to the lifetime of the boat. Examination of the deposits by way of X-ray diffraction reveal that the deposits contain mostly TiB<sub>2</sub> and AlN. Additionally some amount of AlB<sub>12</sub> could be found.

From the results we have derived the following equations with regard to the corrosion mechanism during operation:



There are two processes which occur during the operation of boats:

1. Formation of an AlN layer over the whole cavity. This is an important prerequisite for a long life time since AlN is resistant to molten Al.
2. Development of TiB<sub>2</sub> deposits, primarily at the sides of the cavity. The TiB<sub>2</sub> is transported to the edges by a dissolution/precipitation mechanism.

These mechanisms are most likely to be influenced also by impurities and the microstructure.

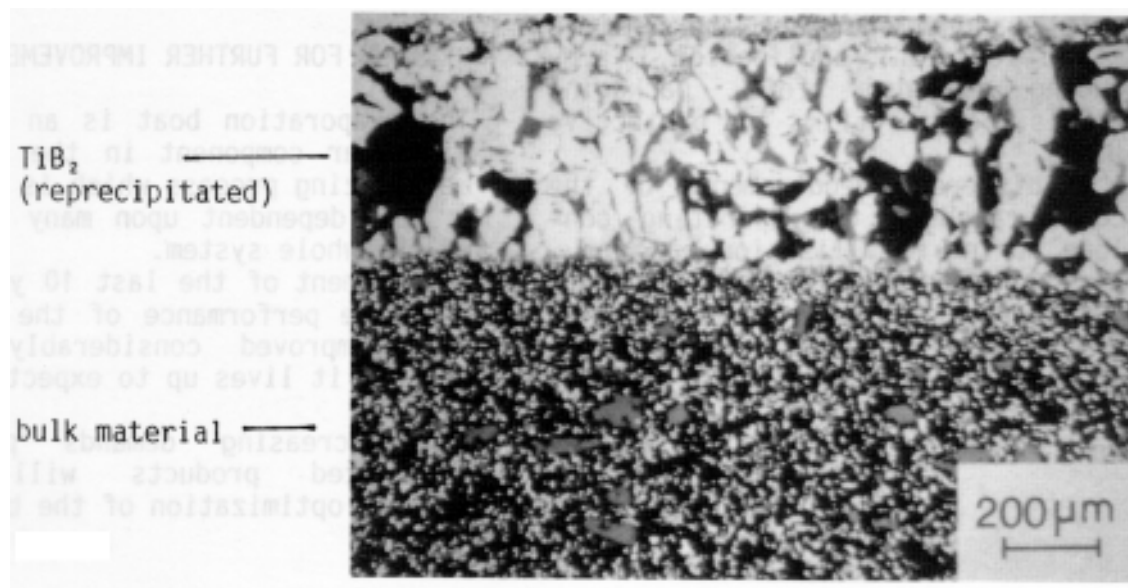
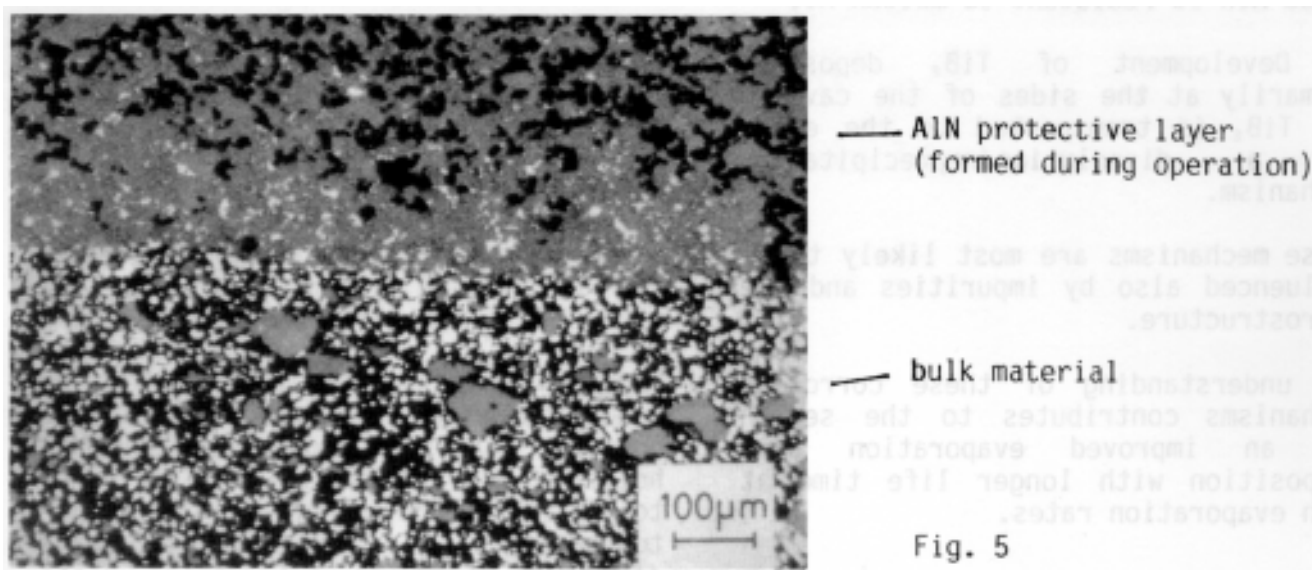
The understanding of these corrosion mechanisms contributes to the search for an improved evaporation boat composition with longer life time at high evaporation rates.

## DEMANDS PLACED UPON EVAPORATIONS BOATS

Ceramic evaporation boats are used in many fields of application, e.g. producing condenser foil, packaging materials, barrier films and protective coatings.

Due to different requirements of the Al-coated product the operating conditions during metallisation can vary. As a result the evaporation boat must also satisfy different requirements. From the point of view of the boat manufacturer this means the following:

The following pictures show micrographs of various polished cross-sections of used boats (Fig. 5 mean-area of cavity, Fig. 6 side of cavity)



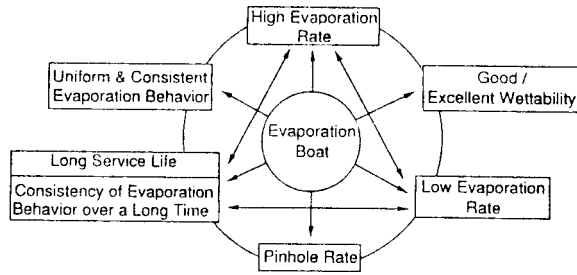


Fig. 7: Requirements for evaporation boats

Conditions like stable evaporation rates and sufficient wettability are crucial to the boat and the metallizing process.

However, our research also shows that certain requirements cannot be met 100 % in every area. For example, tradeoffs have to be made between excellent wettability and long life time.

Demands placed on the material to be metallized, be it thickness of the coating, barrier properties or pin holes lead us to assume that in order to optimize the boats, further customization is required. This means different types of evaporation boats for different applications.

#### OPTIONS FOR FURTHER IMPROVEMENT

The evaporation boat is an important, high-wear component in the continuous metallizing process which is influenced by and dependent upon many parameters of the whole system. Development of the last 10 years shows that the performance of the boats has been improved considerably and in general it lives up to expectations.

The increasing demands placed on metallized products will require further optimization of the boat.

On the one hand the boat manufacturer has several options for further improvement. These could be

- . Variation of the chemical composition, e.g.,
  - higher metal boride content to improve wettability
  - lower metal boride content to increase corrosion resistance
  - replacement of AlN by BN or another refractory material
- . Specially designed coating of the cavity to enhance wettability by Al or other metals like Ag, Cu.

On the other hand it has to be pointed out that many other parameters that are not controlled by the boat manufacturer influence the efficiency and life time of the boats. Examples are

- . Vacuum level in the chamber
- . Electrical contact of the boat
- . Purity of the Al-wire
- . Water cooling system
- . Operating temperature etc.

#### CONCLUSION

The development of the evaporation boats during the last years has led to a high quality standard.

Future optimization needs joint efforts of all parties.

Performance problems will be successfully handled, if

- the manufacturer of the metallizer,
  - the operator of the metallizer,
  - the boat manufacturer
- engage in open and critical communication.