RF Plasma Zone Melting Apparatus

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The characteristics of a RF plasma for the crystal growth of nitrides with high dissociation pressures are described. The electrical behavior measured with a new ammeter is sensitive to both gas composition and ambient pressure. A VN rod was melted under optimum conditions of 400 torr in an Ar-N2 mixed plasma to demonstrate that the present crystals have nearly the same composition as those obtained by RF induction heating under 10 atm of nitrogen. This is direct evidence of chemical dissociation of nitrogen from the melt being suppressed by means of the RF plasma gas.

KEY WORDS: RF plasma; glow discharge; arc discharge; zone melting.

1. INTRODUCTION

The refractory nitrides have high melting points and high dissociation pressures. Therefore their crystal growth by RF induction zone melting techniques allows the nitrogen atoms to evaporate and to escape easily from the melt due to dissociation of nitride. 1,2 In order to overcome this problem, a new process is developed using a well-focused RF plasma flow for the crystal growth of nitrides in which escape of nitrogen is suppressed by the plasma gas pressure. The escaping nitrogen from TiN films treated with the Ar-N2 RF plasma microjet is replenished in the films by the nitrogen component in the plasma gas. 3

The use of plasmas for zone melting has been limited to d.c. plasmas, 4 which results in erosion of electrode materials with subsequent contamination of the plasma. In contrast, RF plasmas produced by inductive coupling

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are not contaminated. However, the large cross section of the plasma torch prevents focusing of the plasma for zone melting.

In view of these circumstances, we have designed an annular plasma jet for RF plasma zone melting, which made it possible to alloy the melt with the composition of the plasma gas. In order to obtain plasma stability and to melt the specimen with good reproducibility, the discharge mode must be controlled after measuring its electrical behavior. However, measuring the $I_{RF}$ vs. $V_{RF}$ curve at several MHz is more difficult than in a d.c. discharge.

The present paper describes the electrical behavior of the new RF plasma jet. For this purpose, an ammeter using direct-current conversion is designed. Utility of the present technique for the crystal growth of nitrides was confirmed by comparing the composition of the crystals with that produced by conventional RF induction heating.

2. EXPERIMENTAL

The furnace is designed to operate from ambient gas pressures up to 10 atm. The chamber (300 cm$^3$ in volume) is made from stainless steel and has a 15-mm-thick wall. The plasma generator is an annular planar jet developed from a RF plasma microjet generator. The annular plasma gun is composed of four sections (Fig. 1). Four quadrant plasma guns 1 are combined into an annular shape and a grounded electrical conductive specimen 4 is set up facing the annular opening of the plasma gun with a spacing of 0.5~1.0 mm. The detailed construction of the RF plasma gun is described elsewhere. By applying a RF potential to the electrode 5 from the RF supply through the cooling water inlet pipe 8, a RF discharge is initiated between the tip portion 5b of the electrode 5 and the specimen 4. The discharge is then pushed along by the gas flow to establish a steady and stable plasma flow. The flow of gas between the electrode plate 14 and the wall 2 serves to direct the plasma on both the upper and lower sides onto the specimen 4. After the chamber is evacuated to $10^{-3}$ torr it

![Fig. 1. Sketch of the annular plasma generator: (1) plasma gun; (2) discharge chamber; (3) opening; (4) specimen; (5) discharge electrode; (6) convex part of the discharge chamber; (7) insulating spacer; (8, 9) water inlet and outlet pipes; (10) electrode supporting plate; (11) insulating adapter; (12) RF supply; (13) gas inlet pipe; (14) electrode plate; (15) spacer; (16) screw.](image-url)