Formation of Ultra High Pure Metal Thin Films by Means of a Dry Process

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Metal thin films or materials surfaces have been playing an important role in many practical applications such as VLSI technology. It is necessary to know both the bulk and surface properties of these materials for their practical applications. To obtain very pure metal films, ion beam technology is the most sophisticated method. Theoretically, it offers isotopically pure thin films (IPTF). The combination of a mass-analyzing process and an ultra-high vacuum environment will achieve it. Negative ion beam technology is proposed for obtaining ultra-high pure thin films.

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1. Introduction

The purification of metals reveals their true character. Some phenomena recently observed really exploded the established theory of metals. For example, Abiko’s group showed that a Fe–Cr compound was successively drawn out to a tube-shape, which was impossible before highly purification of both metals.¹ His group has also shown that the ultra high purity iron has a similar corrosion toughness to aqua regia as that of gold.² On the other hand, thin films or materials surfaces have been playing important roles in some practical applications. In fact, when it comes to use a material practically, the surface is sometimes modified by thin film coatings or other techniques for improving its physical and mechanical properties. After the modification, the material has better toughness for corrosive environments or is lasting longer for use as a tool. In other words, the surface properties may be a limit for the applications of materials. Good surface treatments may highly improve the performance of a poor bulk material. Thus it is necessary to know not only bulk but also surface properties for a good understanding of materials and for their practical applications.

In this paper, the negative ion beam technology is proposed for obtaining ultra-high pure thin films. To obtain very pure metal films, ion beam technology is considered to be the most sophisticated method. Theoretically, it offers isotopically pure thin films (IPTF). The combination of a mass-analyzing process and an ultra high vacuum environment will achieve it. The isotopes in materials may play the role of an impurity for some properties, like for thermal conductivity, for example. A report shows the thermal conductivity of CVD-diamond which was fabricated from ²¹C/²³C ratio enriched gas is 1.5 times larger than that of the normal diamond. Furthermore, the band gaps of diamond, silicon and germanium are varied by isotopically enrichment.³, ⁴

The use of a negative ion beam direct deposition method has been applied as a new way to obtain highly pure thin films. Mass-analyzed low energy negative ions are deposited directly on a substrate to form an isotopically pure film. Since the negative ion source uses only low-pressure argon gas, deposition circumstances can be kept very clean, which means reduction of inclusion of impurities such as oxygen in the film.

2. Low Energy Negative Ion Beam Line

The system being developed in our group deposits low-energy negative ions, which are mass analyzed, directly on a substrate in an ultra high vacuum UHV deposition chamber.⁵ The schematic of the apparatus is shown in Fig. 1. The system consists of a negative ion source, a sector-type 90° mass-analyzing magnet, and beam line including deceleration lens, which are connected to a UHV deposition chamber. The ion beam arrives at the substrate surface with normal incidence.

The negative ion source is an argon sputter type as shown in Fig. 2.⁶ The cylindrical multicusp plasma container is a tube of 60 mm in diameter and 60 mm in length made of stainless steel. It is equipped with a sputter target of 25 mm in diameter, consisting of nickel disks for obtaining nickel negative

Fig. 1 Schematic diagram of the mass-analyzed negative ion beam direct deposition apparatus.
Rutherford backscattering spectrometry (RBS) experiments were performed by means of 1.81 MeV He$^+$ ions in order to check the composition of the films. Figure 5 shows Rutherford backscattering spectrum (RBS) of a deposited nickel film on a glassy carbon substrate produced by means of negative ion beam direct deposition method. The Rutherford backscattering probe was a 1.81 MeV He$^+$ ion beam. Solid line shows a result of a computer simulation.
A new method, i.e., negative ion beam direct deposition method, has been developed to fabricate very pure metal films. The method applies a mass-analyzed negative ion beam source. This ion source is a very good tool for producing isotopically pure thin films. Since some elements such as silicon are not suitable for being used as vacuum arc ion sources, employing both negative ion beam source and arc sources will allow depositions of almost every metal. The negative ion beam direct deposition method is a practical process that can be applied to produce very pure thin films as demanded by the miniaturization processes in the VLSI technology.

REFERENCES