Superconducting transition-edge sensors (TES) can detect the electromagnetic radiations in a wide range from millimeter, optical to γ-ray. The critical temperature ($T_c$) of superconducting films is very important since it determines the key parameters of TESs, including noise equivalent power (NEP), energy resolution, response time. Ti film is a good candidate, and its $T_c$ can be tuned by changing the thickness, bilayer or baking.

In fact, Ti thin films have been widely used in many applications, such as terahertz bolometers and optical photon detectors[1]. We have developed a 8×8 TES array with a NEP of $5\times10^{-17}$ W/$\sqrt{\text{Hz}}$, and optical single photon detectors based on Ti TESs with a detection efficiency of 40%. Here we further tune the $T_c$ of Ti thin films with magnetic field and baking in air atmosphere.

We fabricated pure Ti or Ti/Au films with different thicknesses on silicon substrate by electron beam evaporation [2]. Resistance measurement was carried out in a commercial physical property measurement system (PPMS) equipped with an adiabatic demagnetization refrigerator (ADR), and the base temperature is about 100 mK. We obtained a $T_c$ of 331 mK for a 36.8 nm thick Ti film and it is reduced to 215 mK for a 29.5 nm one. That means it's possible to tune the $T_c$ of Ti film by changing its thickness. However it's hard to decrease the $T_c$ further since the superconductivity disappears while reducing its thickness below 25 nm. The transmission electron microscopy (TEM) showed that titanium films grown in our condition were multi-crystalline, confirmed by x-ray diffraction spectrum. We also measured the chemical composition with a ESD and found that there was 2~3% oxygen atoms throughout the whole thickness, and the oxygen composition was increased to 9% for such titanium films without superconductivity.

We then studied the effect of magnetic field on $T_c$ of Ti films (see Fig.1). With the increase of magnetic field from zero to 600 Gauss, $T_c$ was decreased from 331mK to 210 mK for 36.8-nm Ti film. The transition width nearly keeps constant, that means the temperature sensitivity ($\alpha=T/R\times dR/dT$) has no change within the range of measured magnetic field.

Finally, we tried to tune $T_c$ by baking Ti films at 100°C for time between 5 and 30 hours in air atmosphere. The change in $T_c$ ($\Delta T_c$) was measured by finding a $T_c$ for each sample, baking the sample and measuring its $T_c$ again. For a 31.4 nm Ti film fabricated on 1550nm dielectric mirror, $T_c$ was decreased from 304 mK to 235 mK when baking it for 10 hours ($\Delta T_c$ of 23%). In comparison, for 48/5nm Ti/Au bilayer $T_c$ was decreased from 340 mK to 291 mK when baking it for 30 hours, about 14% change in $T_c$. The results indicate that it's possible to tune the $T_c$ of both pure Ti and Ti/Au bilayer films, although 5nm Au film is a good protection layer for its underneath Ti film. We are going to tune the $T_c$ of Ti TES and will present it in detail.

REFERENCES


NOTES:

1 Purple Mountain Observatory, CAS, China.
2 Key Lab of Radio Astronomy, CAS, China.
3 University of Science and Technology of China, China.