Tuning of superconducting Ti and Ti/Au bilayer films for transition-edge sensors

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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 5×10^{-17} W/√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.

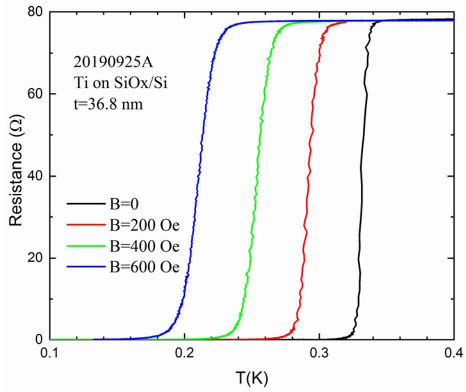

Fig. 1. Resistive transition of 36.8nm thick titanium film with different magnetic fields.

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 (ΔT_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 (ΔT_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

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