Fabrication of a-axis oriented Y-123/Pr-123 muti layered thin film Josephson junctions

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1. Introduction

The Josephson junctions are very sensitive to the external electromagnetic environments and when it is irradiated by microwave a constant voltage plateaus appears in current-voltage (*I-V*) characteristics in a sequence of equality separated voltage. In case of array of Josephson junctions the steps appears in giant value and shows the collective response of many Josephson junctions. The suppression in critical current is occurred with microwave irradiation. This unique property of Josephson junction can be applied in many applications such as superconducting quantum interface device (SQUID), high frequency devices, voltage standered, photon detection, and many more. In this study, we have grown multi layered a-axis oriented both Y123 and Pr123 which works as the Josephson junction along the perpendicular direction to the substrate [1]. A submicron stack has been fabricated in multi layered film using 3-D focused ion beam (3D FIB) milling technique. The stack is such a way so that current will flow in the perpendicular direction to the substrate and stack works as the Josephson junction. The *I-V* characteristics have measured with microwave irradiation. The critical current is showing their response with external microwave.

2. Experimental Details

The a-axis oriented and c-axis in-planed multi-layered thin films are grown using pulsed ArF excimer laser deposition (PLD) method. The thin films are grown on $SrLaGaO_4$ (SLGO) substrates with Gd_2CuO_4 (Gd214) bufferlayer of 50 nm. The Gd214 buffer layer is grown at the substrate temperature of about 730 ºC in a 40 mTorr oxygen pressure. The substrate temperature is monitored by a thermocouple and calibrated by an optical pyrometer. The pulse frequency of the laser was 1Hz and the growth time was 5 min.

The sintered ceramics target of Y123 containing a P123 rectangular region in middle is used to grow the Y123/P123 multi-layered thin films. The alternate layers of Y123 and P123 are grown on the substrate by the rotation of targets during the growth of the thin films. The thickness of Y123 and P123 are 50 nm and 20 nm respectively. The Y123/P123 multi-layered films are grown in a 400 mTorr oxygen pressure. The substrate temperature was around 700 ºC and the pulse frequency of the laser is 5 Hz.

The alternate layers of Y123 and P123 gives the phenomenon of Josephson junction. We fabricate a submicron stack which has Josephson junction in perpendicular direction to the substrate. The submicron stack is fabricated using three dimensional focused ion beam etching technique. In the FIB we have freedom for tilled up to 60º and rotation up to 360º. We use sample stage that is itself 60º incline with Ion beam. We tilt sample stage with 30º so that the *bc*-plane of sample is perpendicular to ion beam and mill along the *bc*-plane. We turn back sample stage in the initial orientation and give the rotation of 180º so that the incline plane is making 60º with ion beam. We tilt sample stage by 60º so that the *a*-axis of Y123 is perpendicular to ion beam and mill along the a-axis in this oriented ion which fabricate two Josephson junctions of area about 300 nm x 150 nm x

200 nm [2]. Inset in fig. 1 shows an FIB image of the submicron stack.

For transport characterization, we performed resistance-temperature (R-T) characteristics and current-voltage (I-V) characteristics using four probe technique. We used low pass filter on signal line to reduce the external noise.

3. Results and Discussion

Figure 1 shows the *R-T* characteristics of multi layered thin film of Y123/P123. We notice a sharp and single phase transition temperature ON (T_{cON}) of about 71 K and T_{cOFF} about 67 K. The transition width (ΔT_c) of the multi layered thin film of Y123/P123 is about 4K. The low value of ΔT_c reflects good quality of thin film grown by PLD.

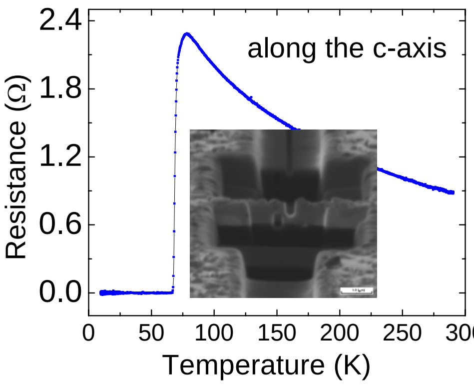

Fig. 1. *R-T* characteristics of multilayered thin film of Y123/P123 show a transition temperature ON at 71K with the transition width of 4 K. Inset shows FIB image of the submicron stack fabricated on a multi layered thin film.

The value of ΔT_c for submicron stack is found higher than the multi layered thin film which can be the effect of ion irradiation during the fabrication process. We have measured *I-V* characteristics of submicron stack fabricated on multi layered thin film of Y123/P123. The measurement has done with different power of microwave 10GHz at 30K.

The suppression in critical current is occurred when we apply the microwave with any power. The maximum suppression is occurring at +15 db power of 10 GHz frequency of microwave. Fig.2 shows the *I-V* characteristics of submicron stack with 10 GHz of microwave frequency at different power at 20K. The deviation in the voltage step value shows it is affect of flux flow behavior.

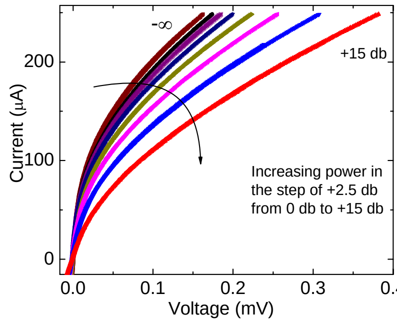

Fig. 2. *I-V* characteristics of submicron stack at 20 K and 10 GHz at different power of microwave.

4. Conclusions

We have fabricated a submicron stack in multi layered thin film of Y123/P123 using 3-D FIB etching. The transition temperature for multi layered thin film starts from 71 K with a transition width of 4 K. The critical current of about 0.12 mA appeared at 30 K in *I-V* characteristics. We notice suppression in critical current as the effect of external effect of microwave at different power. As we increase the power, the superconducting state is suppressing and resulting to suppress the critical current. Further improving this work we have fabricated two stack devices and measuring the transport characteristics with microwave irradiation.

References

1. Corlevi S., Guichard W., Hekking F.W.J., and Haviland D.B., "Coulomb blockade of cooper pair tunneling and parity effects in the cooper pair transistor", Phys. Rev. B **74**, 224505, 2006.
2. Kim S. -J., Latyshev I. Yu., Yamashita T., "3D intrinsic Josephson junctions using *c*-axis thin films and single crystals" Supercond .Sci. Technol. vol **12**, 729, 1999.