NbN ultrathin films fabrication technology for THz range hot-electron bolometers

Ivashentseva Irina

Introduction

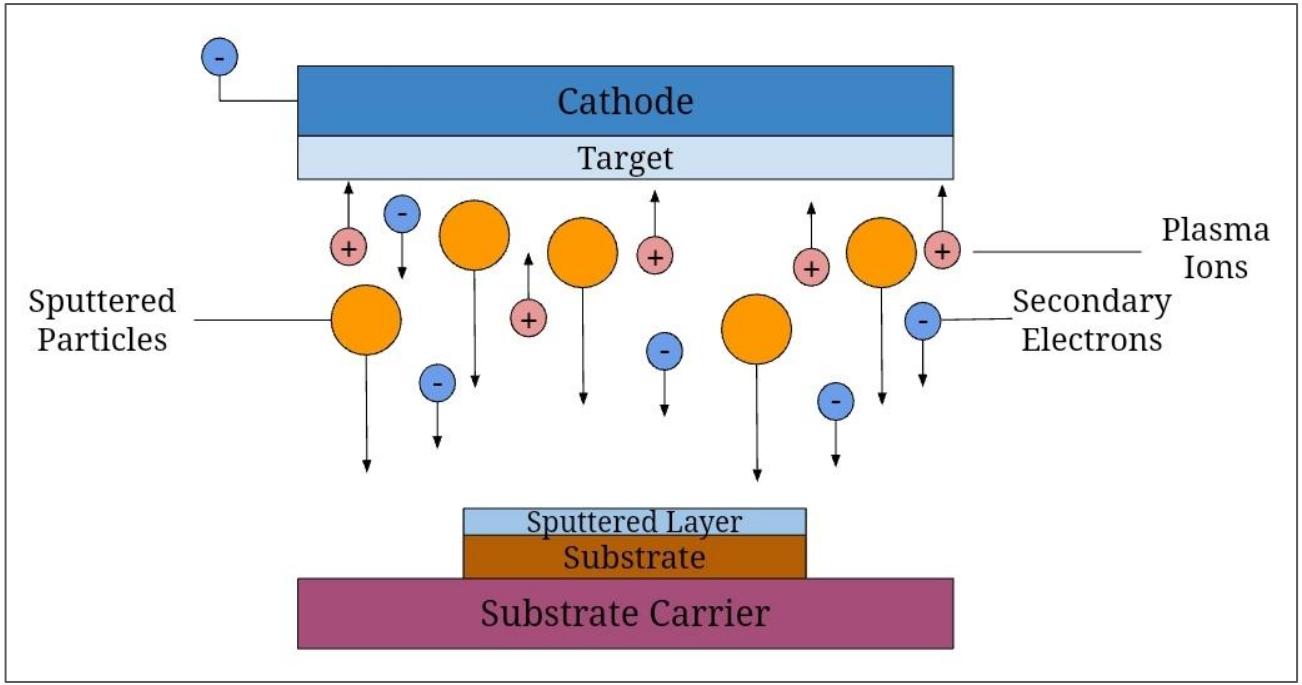
Scientific program of the Millimetron space observatory equipped High Resolution Spectrometer with 7-pixel matrix receivers based on NbN HEB mixers for frequencies above 1.3 THz.

Problem of current fabrication technology is that every HEB mixer require individual adjustment of the bias voltage and the LO power but this is not applicable for 10-pixels HEB matrix.

The main goal of work is fabrication of ultrathin films with maximum T_c and minimum spread of surface resistances sputtered in one process for concrete deposition technology.

Cathode Sputtering

- **High accuracy of film composition**
- **Great complexity of technological parameters control**



Fabrication of films

Cathode sputtering system
Leybold Z400

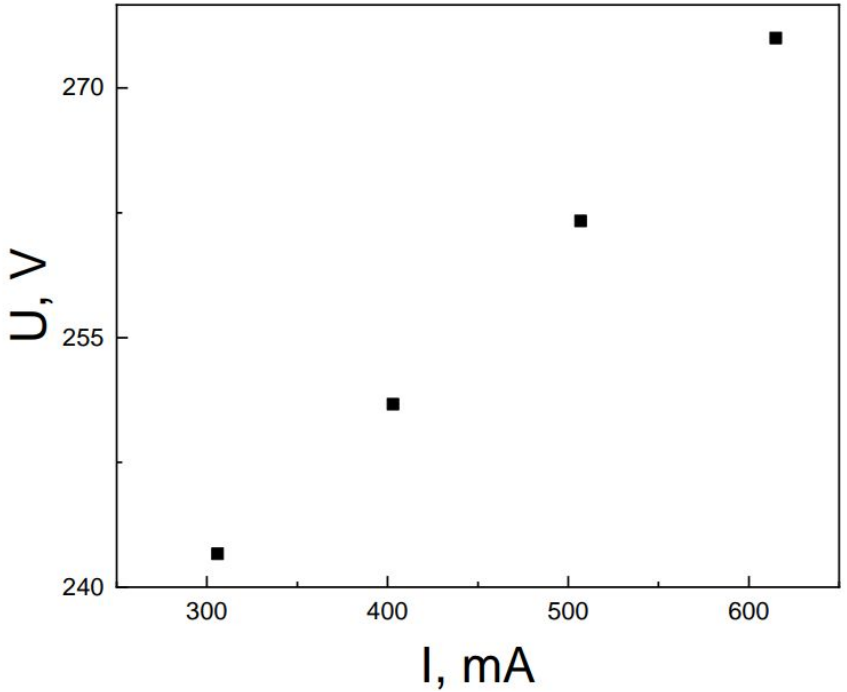
Parameters of cathode sputtering:

- Nb cathode diameter
- Distance between substrate carrier and Nb cathode
- **Si substrate arrangement on substrate carrier**
- Chamber vacuum pressure P_0
- **Cathode current I**
- Substrate carrier temperature T_s
- Ar gas pressure P_{Ar}
- **N_2 gas pressure**
- **Voltage on Ar and N_2 gases, U_{sum}**
- Sputtering time τ
- **Purity and surface roughness of the silicon substrates**

Cathode current and sputtering time

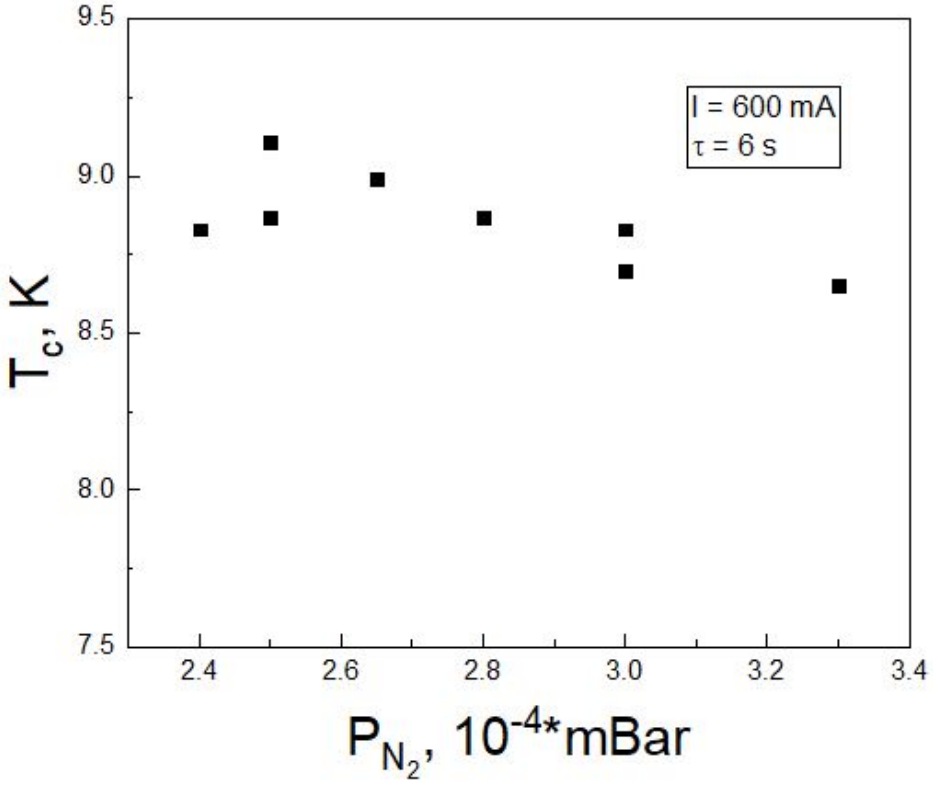
9-9.5 nm films time sputtering for various current

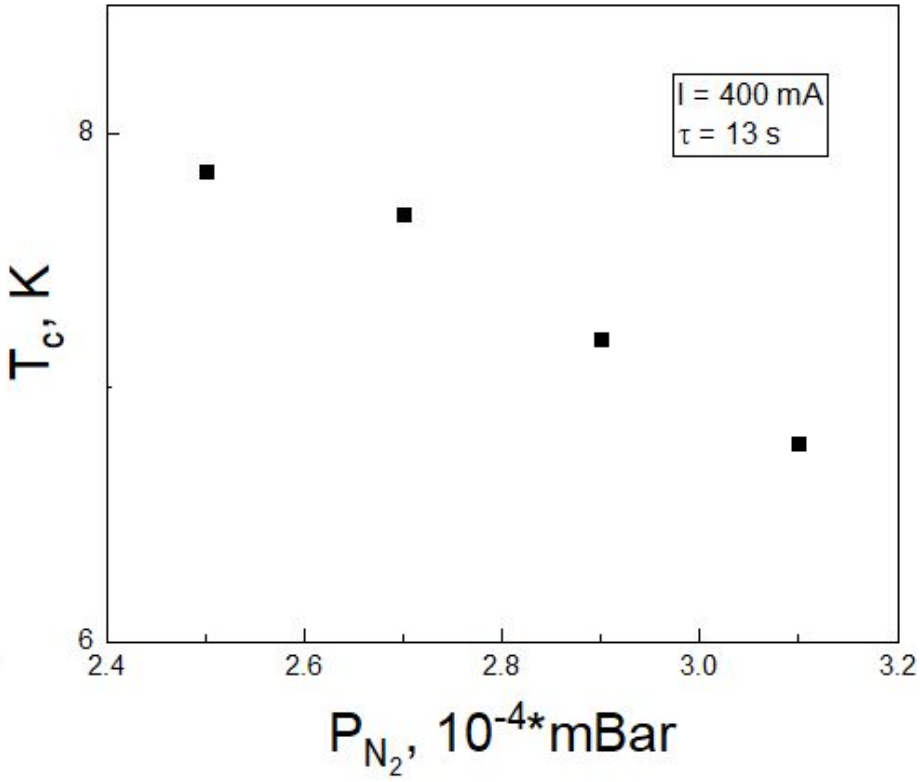
I, mA	τ, s
400	13
500	10
600	6



Abnormal glow discharge

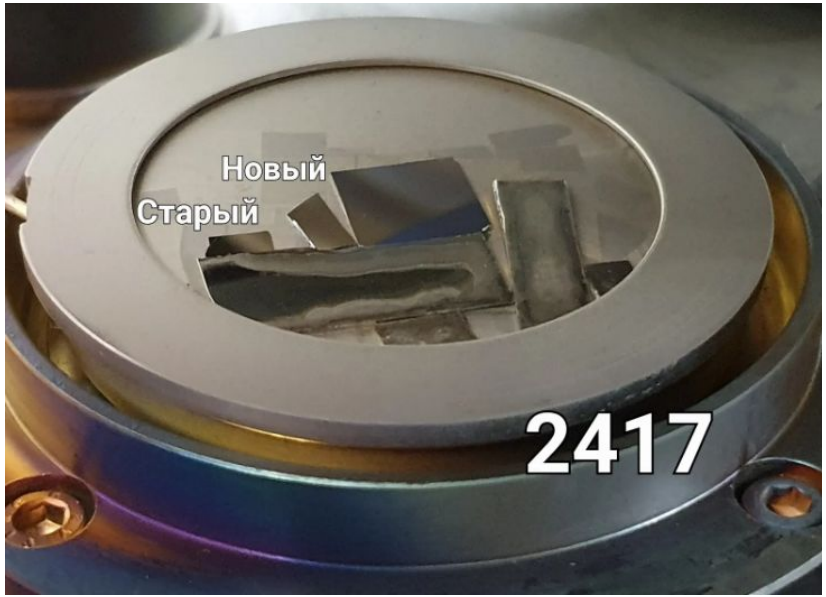
T_c dependence from N_2 pressure for 600 and 400 mA





Maximum T_c = (2.5-2.6)*10^{-4} mBar

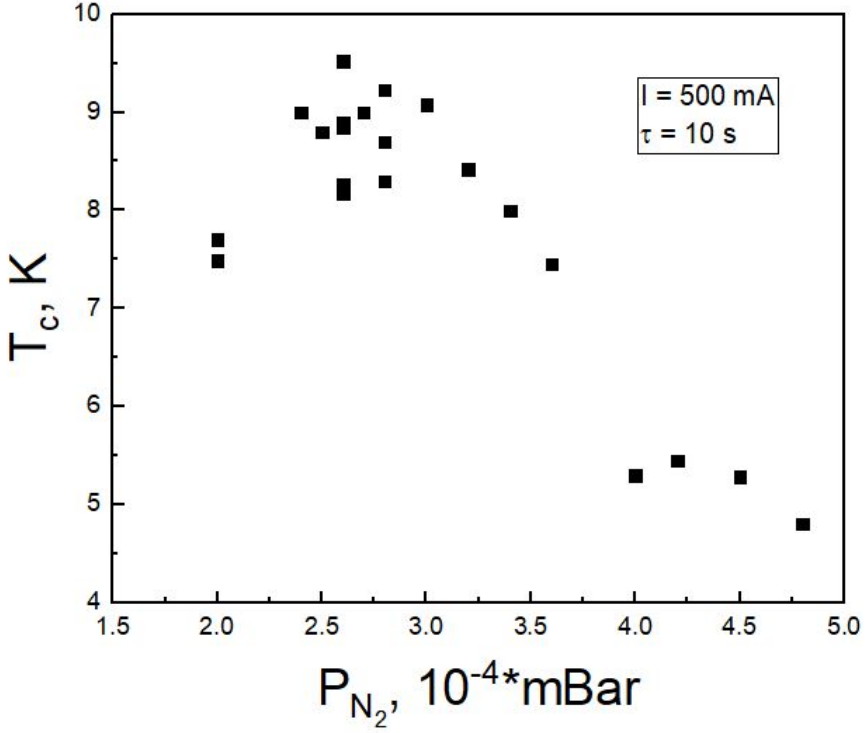
T_c deviation on substrate carrier

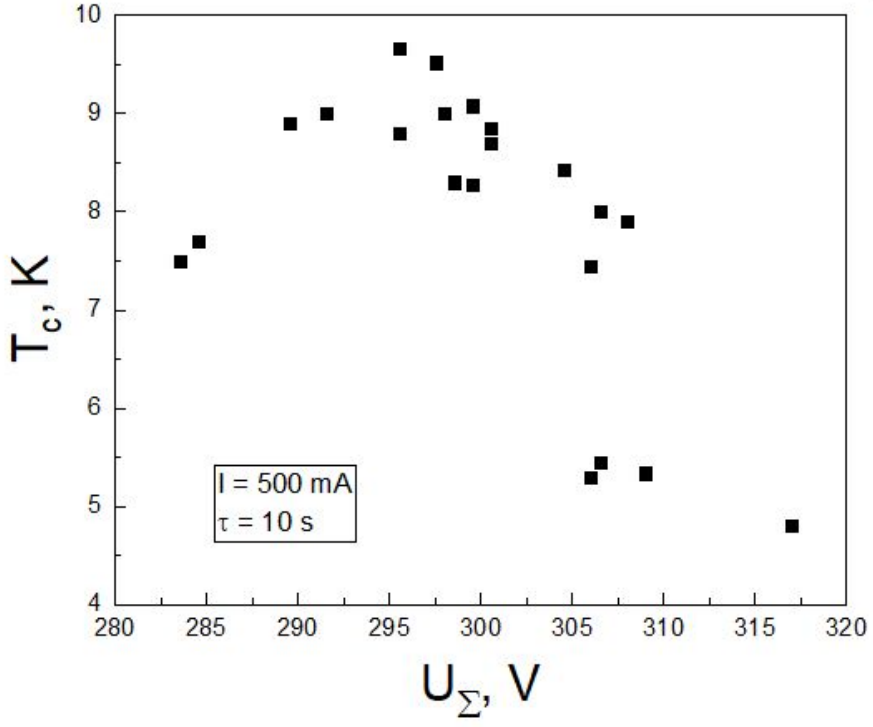


3-inch substrate carrier

Sputtering process	T_c, K	$\pm T_c$, K
2410	8.70	0.05
2411	8.93	0.1
2412	8.83	0.05
2413	8.63	0.05
2414	8.35	0.05
2415	9.17	0.05
2416	8.06	0.2
2417	8.75	0.05
2419	9.32	0.15
2421	7.64	0.2

Dependence T_c from P_{N2} and U_{sum}



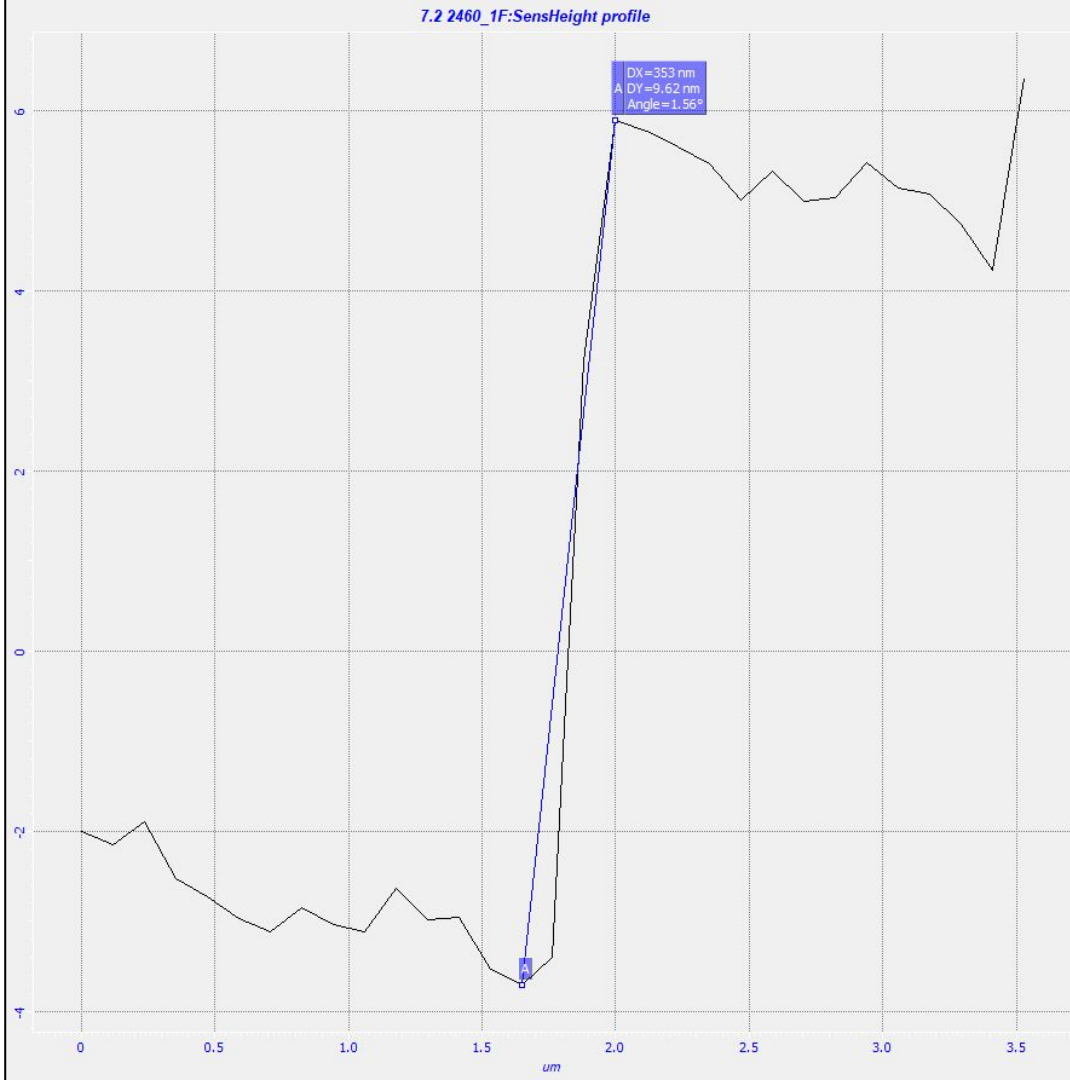


Films 9.5 nm with T_c=8.5-9 K for P_{N2}=2.5 mBar*10^{-4} and U_{sum}=295-296 V

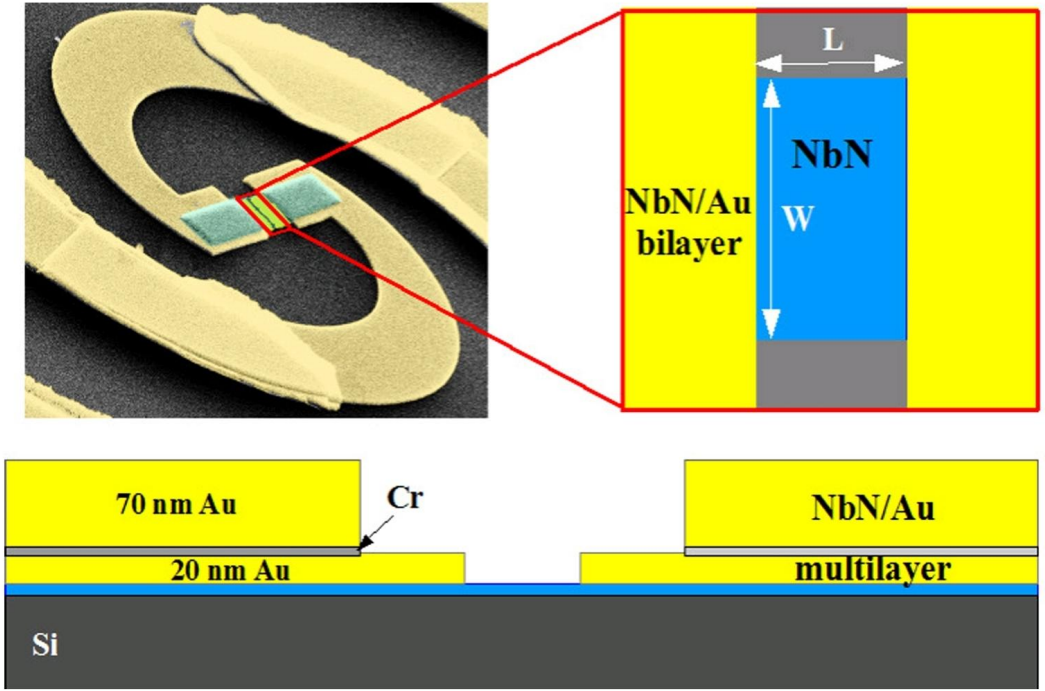
AFM film thickness

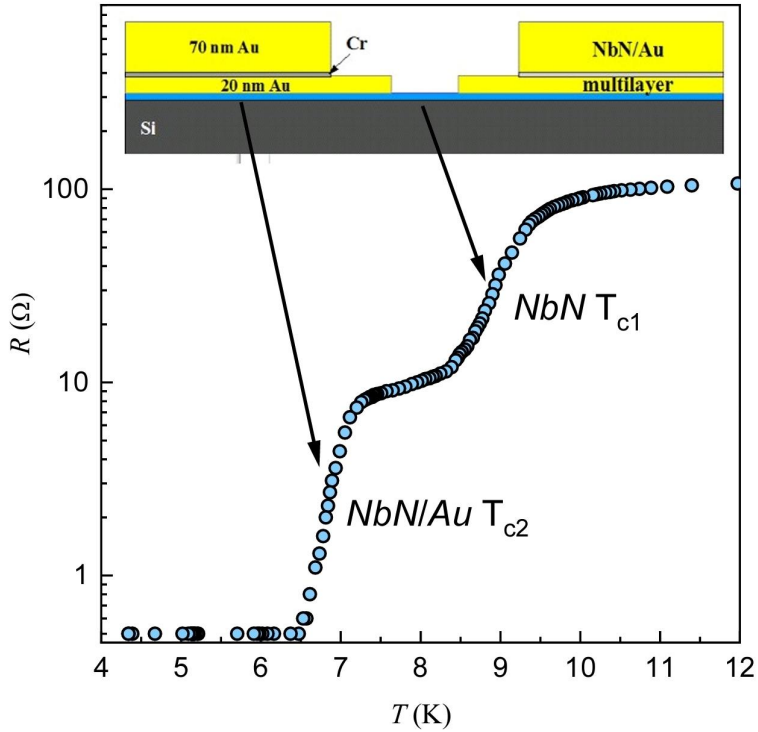
P_{N2}, mBar*10^{-4}	Thickness, nm
2.1-2.8	9.5±0.5
3.8-4.2	8.2±0.5

10 s time sputtering



Hot-electron bolometers





Results

Parameters of cathode sputtering:

- 3-inch Nb cathode diameter
- 5-cm distance between substrate carrier and Nb cathode
- Si substrate arrangement on substrate carrier does not influence on T_c
- Acetone/deionized water/isopropyl alcohol per 10 minutes each in an ultrasonic cleaning machine at temperature 49°C
- $P_0=(1.7\text{-}2.6)*10^{-6}$ mBar
- I = 500 mA
- T_s = 400 °C
- $P_{Ar}= (9.4\text{-}9.9)*10^{-3}$ mBar
- $P_{N2}= 2.5*10^{-3}$ mBar
- τ = 10 s
- U_{sum}=295-296 V and ΔU = 43-45 V
- 9-9.5 nm

Purity and surface roughness of the material

Series	Film cleaning type	T_c, K	R_s, Ohm/□
A3706/1	1. Hydrofluoric acid etching HF:H2O 1:10 30 sec	8.5	480
A3706/2	1. Oxygenic plasma 150W 5 min Corial 2. Hydrofluoric acid etching HF:H2O 1:10 30 sec	9.1	490
A3706/3	1. Oxygenic plasma 150W 5 min Corial	9.5	514

Conclusion

In the present work such parameters for NbN films fabrication as purity and surface roughness of the silicon substrates, Si substrate arrangement on substrate carrier, cathode current, N_2 gas pressure, voltage on Ar and N_2 gases sputtering process were considered.

P_{N2}= 2.5*10^{-3} mBar, U_{sum}= 295-296 V comply with T_c = 8.5-9 K for 9-9.5 nm NbN on Si substrate films were specified.

Increase of substrate carrier temperature and improvement of the quality cleaning of substrate surface will enlarge T_c in future works.