Characterization of Superconducting TiN Thin Films Properties Developed at Different Substrate Temperature

情通機構　°丘　偉，寺井　弘高
NICT　°Wei Qiu, Hirotaka Terai
E-mail: qiuwei@nict.go.jp

Experiment and results

Titanium nitride (TiN) superconducting material has been under intensive studied in recent years due to its supreme performance in superconducting quantum circuits, such as low-loss superconducting coplanar resonator for superconducting qubit application, or realization of high-quality full-epitaxial NbN tunnel junctions on Si-substrate, both served as the crucial element for developing large scale superconducting qubit arrays. In our latest TiN resonator device, quality factor Q has been achieved by DC magnetron sputtering method. However, to further improve its performance, systematic investigation the property of TiN films is needed. In this letter, we study the properties of TiN films developed under different substrate temperature, varied from 250 ℃ to 850 ℃. For each condition, the Si wafers was treated by hydrogen passivation with BHF prior to the TiN film deposition. TiN films surface morphology was analyzed by X-ray diffraction (XRD) and SEM methods. XRD results showed sharp peaks at θ/2θ=42.6. TiN (200) for TiN films deposited at substrate temperature above 650 ℃. Superconducting properties of TiN films have been examined by the R-T measurement. London penetration depth λ_L, as well as kinetic inductance L_k were estimated from the resonance shifts patterned from TiN films obtained at different substrate temperatures (Table I).

T_{sub} (℃)	T_c (K)	ρ_{10K} (μΩ cm)	RRR	f_{design} (GHz)	$f_{mea.}$ (GHz)	λ_L (nm)	L_k (nH/m)
850	5.60	3.2	5.4	9.275	8.8624	71	13
750	5.30	4.0	4.5	9.275	8.9010	67	11
650	5.20	5.9	3.4	9.275	8.7244	83	17
550	5.10	6.4	3.3	9.275	8.5863	94	22
450	4.58	16.9	1.8	9.275	8.0117	134	45
350	4.33	24.6	1.5	9.275	7.6223	159	64
250	4.23	41.5	1.5	9.275	7.5569	164	67

Fig. 1.　Properties of TiN films deposited at different substrate temperature from 850 ℃ to 250 ℃. The London penetration depth λ_L were calculated from the resonance shifts in coplanar waveguide resonator patterned from each TiN film.

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