# Electrical performances of Tantalum Nitride Thin Film Resistors (TFR) versus N-content modulation

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Nowadays, precise thin film resistors (TFRs) play a fundamental architectural role in advanced semiconductor power devices, in order to target higher stability, accuracy, and reliability, as well as lower noise for high-precision applications, such as electronic measuring systems, monitoring equipment, audio applications, precision controls and instrumentation.
High resistivity and good thermal stability are crucial properties for the realization of a TFR. Besides well-established alloys such as SiCr or NiCr, another performing class of materials for the purpose is tantalum nitrides (TaN). TaN is known to have a complex diagram phase, forming different stable and metastable phases [1,2], and this leads to a considerable variation in its electrical properties upon deposition conditions and process parameters, such as $N_2$ partial pressure or temperature during sputtering, because they directly impact on chemical composition and structure of TaN films.
In this work, constant-pressure reactive DC magnetron sputtering was used to produce TaN thin films employing tantalum metallic target, nitrogen as reactive gas, and argon as plasma-supporting gas. A set of five different films was obtained by varying $N_2$ flow, ranging from 0 to 20 standard cubic centimeters (sccm). The corresponding electrical properties of these films were investigated: the sheet resistance of the films increases with nitrogen content, in a range between 75 and 1000Ω/□, while the temperature coefficient of resistance (TCR) spans four order of magnitude, between $-10^3$ and +10 ppm/ºC (Fig. 1). TCR expresses resistance variation with temperature: a positive value implies that the resistance of the material increases with a temperature increase, while a negative TCR means that the resistance decreases by increasing the temperature. The ideal condition for high-performance devices is to have temperature-independent resistance. This condition is approached by the new-studied low-nitride TaN (5sccm $N_2$), exploiting the opposite contributions of Ta (+TCR) and Ta-N (-TCR), which allow to achieve a compensation, thus reaching a near-zero TCR value [3].
For the electrical characterization, the study concurrently carried out the integration of all the investigated TaN films in the front-end-of-line of advanced BCD technology on 200mm wafers. The films were integrated upon an oxide layer and capped by silicon nitride to prevent oxidation, providing versatility to be implemented into different modules both in front-end-of-line (FEOL) and within the metallization layers of the back-end-of-line (BEOL). Patterning of these layers was conceived as fully compatible with every N-content layer, employing a single dry etching strategy in combination with a dedicated wet removal to avoid Ta-polymer residues. For TaN etching, a chemistry in $BCl_3$, $Cl_2$, and Ar with good selectivity towards underneath oxide was employed, combined with a wet removal with SPM ($H_2SO_4$ : $H_2O_2$) and SC1 ($NH_4OH$ : $H_2O_2$ : $H_2O$).
The results showed that the new TaN film at low nitride content provided the most promising electrical performances for the required scope. By full integration of TaN films on power components of advanced BCD devices, excellent stability with temperature was proven, reaching a TCR of approximately 150 ppm/ºC and a sheet resistance of 75 Ohm/□, making it an adequate solution for TFR realization. To target higher electrical performances and to approach those of the major competitive materials, such as SiCr or NiCr, further retuning is possible by properly targeting the nitrogen flow and modulating the film thickness to reach higher sheet resistance values. In addition, the single-integration strategy guarantees an easy-to-integrate and manufacturable solution according to device requirements.

**Keywords:** tantalum nitride (TaN); thin film resistor (TFR); sheet resistance, temperature coefficient of resistance (TCR)

### References

1. Y. Hu, Coatings, **11**, 937 (2021)
2. J. Nazon, Journal of Alloys and Compounds, **464**, 526-531 (2008)
3. S. M. Na, Thin Solid Films, **516**, 5465–5469 (2008)

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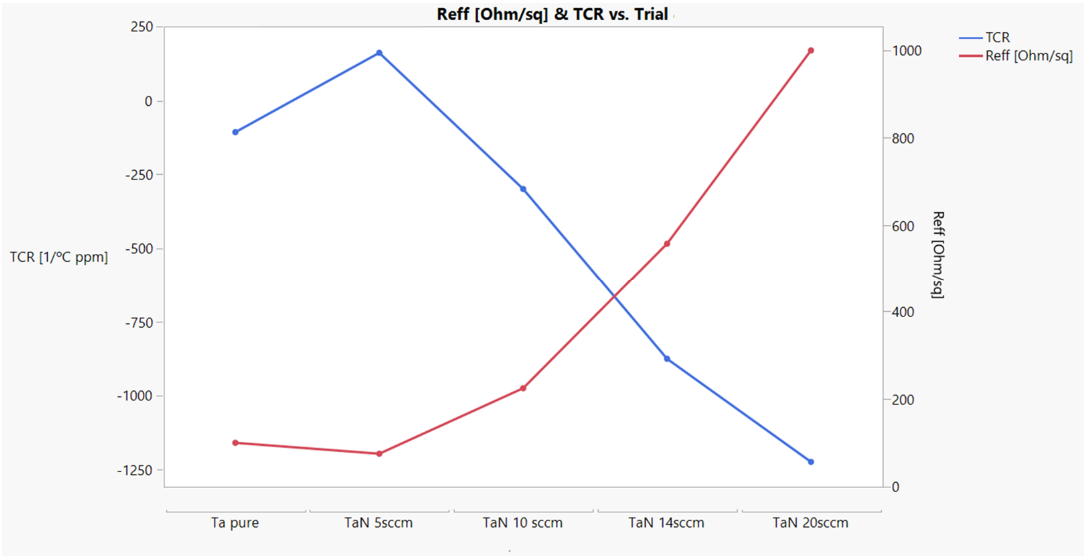


*Figure 1 – TaN sheet resistance (red) and TCR (blue) modulation with $N_2$ flow*