

Accepted Manuscript

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PII: S0040-6090(18)30139-1
DOI: [doi:10.1016/j.tsf.2018.03.002](https://doi.org/10.1016/j.tsf.2018.03.002)
Reference: TSF 36506
To appear in: *Thin Solid Films*
Received date: 15 November 2017
Revised date: 22 February 2018
Accepted date: 1 March 2018

Please cite this article as: Boen Houng, Yung Hui Shih, Jack Wu, Sue Han Lu , Effect of power density on the microstructure and properties of titanium diboride thin films by radio frequency magnetron sputtering method. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Tsf(2017), doi:[10.1016/j.tsf.2018.03.002](https://doi.org/10.1016/j.tsf.2018.03.002)

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Effect of power density on the microstructure and properties of titanium diboride thin films by radio frequency magnetron sputtering method

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ABSTRACT

Thermoelectric generators directly convert heat into electricity and offer a unique and very promising pathway for generating power. Titanium diboride, TiB₂, is an ideal candidate for use as an electrode material in thermoelectric systems because of its refractory characteristic and excellent electrical conductivity. This study reports the effect of sputtering power density on microstructural, electrical and mechanical properties of TiB₂ films fabricated by radio frequency magnetron sputtering. The TiB₂ thin films were deposited at 500 °C with power densities of 5.1–12.7 W/cm². As the power density increased, X-ray diffraction analysis showed a formation trend of highly crystallized hexagonal TiB₂ with a (001) preferential orientation. X-ray photoelectron spectroscopy data revealed that only T–B chemical bonding states were present in the TiB₂ phase. TiB₂ films also exhibited a denser microstructure with a larger grain size. All three factors led to a lowering of the films' electrical resistivity. A minimum electrical resistivity of $6.5 \times 10^{-4} \Omega\text{cm}$ was obtained with a free-electron concentration of $1.2 \times 10^{20} \text{ cm}^{-3}$ and carrier mobility of $86.7 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$. The hardness and elastic modulus were also found to increase with discharge power density from 19.5 to 26.6 GPa and from 165.2 to 196.8 GPa, respectively. This study demonstrated that the combination of high melting point and excellent electrical and mechanical properties makes TiB₂ an ideal electrode material for thermoelectric applications.

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