Enhancement of infrared emissivity of silicon nitride thin films by inducing metallic phases via titanium thermal diffusion

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Abstract

Transition metal nitrides are drawing attention due to their promising mechanical, electrical and chemical properties which are frequently leveraged for industrial and scientific applications such as wear-resistant tool coatings, decorative coatings, thin film resistors, semiconductor gate dielectrics, energy conversion and storage. Among them, Titanium Silicon Nitride (TiSiN) is used extensively due to its excellent hardness, wear and corrosion resistance, and electrical properties. It comprises of metallic and dielectric phases coexisting. From the literature, the infrared mechanism is different for metals (free carrier absorption) and dielectrics (phonon absorption) (1). There are limited reports on the thermal properties of ternary alloys especially their infrared mechanism. Thermal studies become significant when the temperature of such films rises due to friction, light absorption etc.

In this study, we aim at improving thermal emissivity of silicon nitride film by adding titanium. The structure is assumed to be having metallic phases embedded in the dielectric matrix. The Generalized matrix formalism and Bruggeman model for mixed phases are employed to determine the dielectric function of the TiSiN composite film and thereby the emissivity. Titanium with a 10 nm thickness is sputtered onto silicon nitride that has been deposited using PECVD at different thicknesses. The TiSiN was prepared by thermal diffusion of silicon nitride and titanium stack at 900 degrees for 8 hours. Silicon nitride is observed to have negligible absorption in the mid infrared region from simulation and the emissivity is found to be 0.036 experimentally. The emissivity is increased to 0.22 through the thermal diffusion of titanium into silicon nitride films. This work shows that even if the composite consists of dielectric and metallic phases, the infrared mechanism of TiSiN intermetallic film follows more of a metallic trend, providing insight into the role played by metallic phases in emissivity when the film thickness goes thinner. This improvement is attributed to the enhancement of free carrier absorption by the addition of titanium. This research can trigger interest in the use of these thin-films for infrared applications like sensors, detectors, plasmonic devices, IR imaging etc.

Reference

(1) Sheila Edalatpour et al. Size Effect on the Emissivity of Thin Films IMECE2012-88367, pp. 1761-1770; 10 (2013)