Abstract

TiN, TiAlN (Al concentrations vary from low to high atomic %) and TiAlSiN coatings synthesized on AISI M2 steel substrate via unbalanced magnetron sputtered technology were developed for selective solar surface applications. XRD, SEM, UV-Vis and FTIR spectroscopies were used to characterise the crystalline structure, surface morphology, and optical selectivity of the coatings. Optical studies showed that the optical absorbance, in the visible range, of the TiN coatings was improved significantly from 25% to 74% with increase of Al-doping. However, an increase of optical absorbance of up to 50% resulted from coatings doped simultaneously with Al and Si. With the high Al-content, the optical emittance, in the IR range, of TiN coatings decreased from 4.5% to 3.4% whereas simultaneous addition of Al and Si to the TiN coatings resulted in a reduction of the emittance down to 4%. The highest optical selectivity of 21.76 was achieved with Al only doping and 12.50 with simultaneous Al and Si doping to the TiN matrix.

Objectives

In this study we investigated the potential development of magnetron sputtered TiN, TiAlN and TiAlSiN coatings for solar selective surfaces applications.

Materials and Characterisation Techniques

- TiN, TiAlN (Al concentrations vary from 15% to 25% and TiAlSiN coatings synthesized on AISI M2 steel substrate via unbalanced magnetron sputtered technique
- XRD measurements
- SEM and EDAX measurements
- Double beams UV-Vis spectrophotometer (UV-670 UV-Vis, JASCO, USA)
- FTIR spectrometer (PERKIN Elmer Spectrum 100)

Optical Properties

Optical properties of the coatings were analysed by measuring the optical reflectance as function of wavelength via UV-Vis and FTIR spectrometers in the range of IR ~ far IR, respectively. Using the reflectance data, R(λ), the solar absorbance (α) and the solar emittance (ε) of these coatings were calculated using the following equations.

\[ \alpha (\lambda) = \frac{\int_{0}^{\infty} S_{0\lambda} (\lambda) (1-R(\lambda)) \, d\lambda}{\int_{0}^{\infty} S_{0\lambda} (\lambda) \, d\lambda} \]  

(1)

\[ \varepsilon (\lambda) = \frac{\int_{0}^{\infty} I_{0\lambda} (\lambda) (1-R(\lambda)) \, d\lambda}{\int_{0}^{\infty} I_{0\lambda} (\lambda) \, d\lambda} \]  

(2)

The solar selectivity (s) is the ratio of absorbance (in UV-Vis range) and emittance (in IR range).

\[ s = \frac{\alpha (\lambda)}{\varepsilon (\lambda)} \]  

(3)

Results are summarised in Table 3.

XRD Studies

- All three coatings show the TiN phase with (111) orientation. This (TiN (111)) peak is observed to be shifted towards higher Bragg angles as the dopants (Al or Si) are added. This peak shift indicates contraction of lattice unit cell size by the substitution of larger Ti (0.147 nm) doping atoms with smaller Al (0.143 nm) and Si (0.134 nm) doping atoms.
- Due to spinodal decompositions of TiAIN and TiAlAIN coatings, h-AlN and h-SiN, are formed in TiAIN and TiAlAIN coatings [1].
- These decompositions are based on the rise of free energy of TiAIN and TiAIN coatings compared to their constituents. Some sort of possible retarding forces might be also responsible for such decomposition processes [1-2].

SEM & EDAX Studies

- EDAX analysis by field ion microscope of TiN, TiAlN and TiAlSiN magnetron sputtered coatings.

<table>
<thead>
<tr>
<th>Sample</th>
<th>[Al]</th>
<th>Ti %</th>
<th>N %</th>
<th>Si %</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiN</td>
<td>-</td>
<td>88.43</td>
<td>11.57</td>
<td>-</td>
</tr>
<tr>
<td>TiAIN</td>
<td>Low</td>
<td>49.36</td>
<td>15.62</td>
<td>35.02</td>
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<tr>
<td>TiAlAIN</td>
<td>High</td>
<td>32.47</td>
<td>17.50</td>
<td>50.03</td>
</tr>
<tr>
<td>TiAlSiN</td>
<td>-</td>
<td>60.86</td>
<td>15.21</td>
<td>18.80</td>
</tr>
</tbody>
</table>

Conclusion

- Optical selectivity of unbalanced magnetron sputtered TiN coatings, doped with Al and Si, improved significantly.
- Optical selectivity (s/a) increased from 5.5 to maximum of 21.76 for coatings with high Al content.
- Homogeneous, dense and uniform surface microstructure of these 3d transition metal nitride based coatings was induced with addition of Al and Si dopants.

References


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