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Smooth vanadium-nitride layers created on silicon substrates by pulse laser deposition method

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ABSTRACT

Pulsed Laser Deposition (PLD) of vanadium-nitride (V_2N, $V_{10}N_7$) films on Si substrates have been carried out under influence of series of UV (excimer) laser pulses (λ=308 nm, τ_{FWHM}=25 ns) in NH_3 atmosphere of a few mbars. In the reaction cell the Si target has been placed to be parallel to V sheet at angle of 45° to the incident laser beam, and the plasma plume induced by laser pulse reached the target close perpendicularly. The number of shots at fluxes of 30 J/cm^2 were varied between 100 and 5000. Rutherford Back-Scattering (RBS) studies revealed that under influence of laser pulses at Si layer V_2N layers of 100 nm thickness were formed, while the composition of the layer closer atmosphere was $V_{10}N_7$ of 50 nm thickness (in average). In some cases we observed layers of VNCO and $V_{10}N_7C_5$.

Atomic Force Microscopy measurements revealed a formation of quite smooth surfaces with roughness of less than 10 nm. A characteristic wave-like structure with period of 3-5 nm was able to be observed in some cases. XPS examinations showed the existence of well defined peaks of V(2p) lines at 516 eV and 513 eV. Also we observed lines of N(1s) at 397 eV, O(1s) at 529 eV and C(1s) at 284 eV. From these investigations it might be concluded that PLD technique allows growing smooth VN layers on Si with a little, but measurable contamination of carbon and oxygen.

Keywords: vanadium, nitride, silicon, laser, plasma, RBS, XPS, AFM,

2. INTRODUCTION

Vanadium and other metal nitride coatings are of particular interest for a wide variety of applications due to their ability to combine several important physical and chemical properties such as chemical inertness, excellent wear resistance, high hardness etc [1-5].

There are several methods for obtaining metal nitride films [3-5] including various physical and chemical deposition methods. In this work we have applied the Pulsed Laser Deposition method to obtain vanadium nitride layers on the surface of Si single crystal plates.

3. EXPERIMENTAL

The metallic samples of vanadium foils (Goodfellow UK) with size of 40×40×0.3 mm^3 have been placed into a vacuum chamber in a holder allowing to rotate the sample. Silicon wafer have been placed parallel to metal plates of distance of about 10-50 mm. The vacuum chamber has been filled with NH_3 up to pressure of about a few mbars. The laser pulses (λ=308 nm, τ_{FWHM}= 25 ns with fluxes of 30 J/cm^2) have been directed onto the metallic plates (V-sheet) at angle of 45°, therefore the plasma plume induced by laser pulse reached the Si target close perpendicularly.

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The Si plates with vanadium nitride coatings have been investigated by methods of Rutherford Back Scatering (RBS), Atomic Force Microscopy (AFM), optical microscopy and X-ray Photoelectron Spectroscopy (XPS).

4. RESULTS AND DISCUSSION

The irradiation of rotating V samples by pulses of UV laser source working at repetition rate of 10 Hz allowed to reach vanadium nitride coatings at fluence 30 J/cm^2 with number of pulses at about 1000-5000.

4.1 RBS measurements

RBS spectra revealed that depending on the pressure of the ambient atmospheric different VN layers appeared on the surface of Si substrat:

a, At pressures of about 1-5 mbars coatings of V_2N with thickness about 100 nm have been grown
b, At pressures 100-500 mbars layers of $V_{10}N_7$ with thickness about 50-80 nm have been grown
c, At atmospheric pressures we observed the growth of layers of $V_{10}N_7C_5$ with thickness of 40-70 nm

4.2 AFM measurements

Atomic Force Microscopy measurements revealed formation of a quite smooth nitride components on Si targets with roughness of less than 10 nm. Typical AFM picture[5] of layers inventigated are presented in Fig.1.

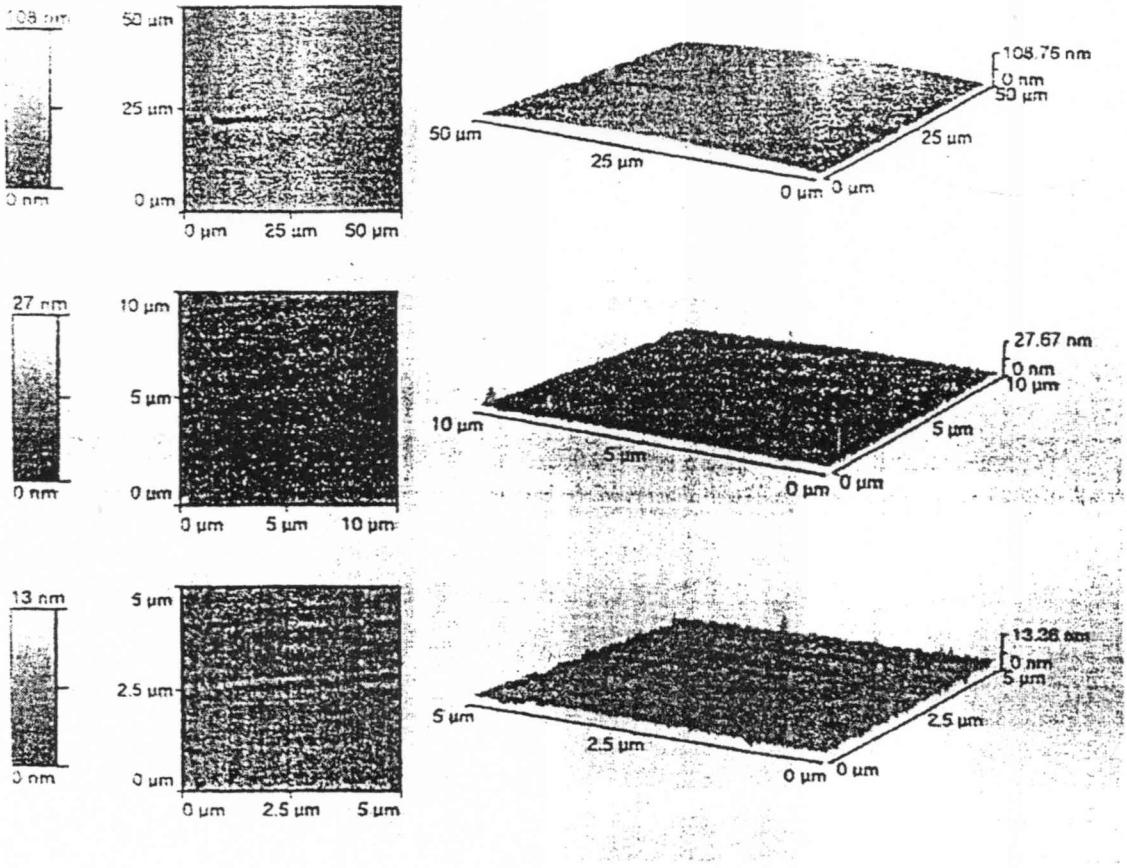

Fig.1: AFM pictures of VN have been registered at different parts of layers.

4.3. XPS studies

XPS examinations showed the existence of well defined lines of V (2p) at 516 eV and 513 eV and N (1s) lines at 396.95 eV. Typical spectra are demonstrated in Fig. 2a and 2b.

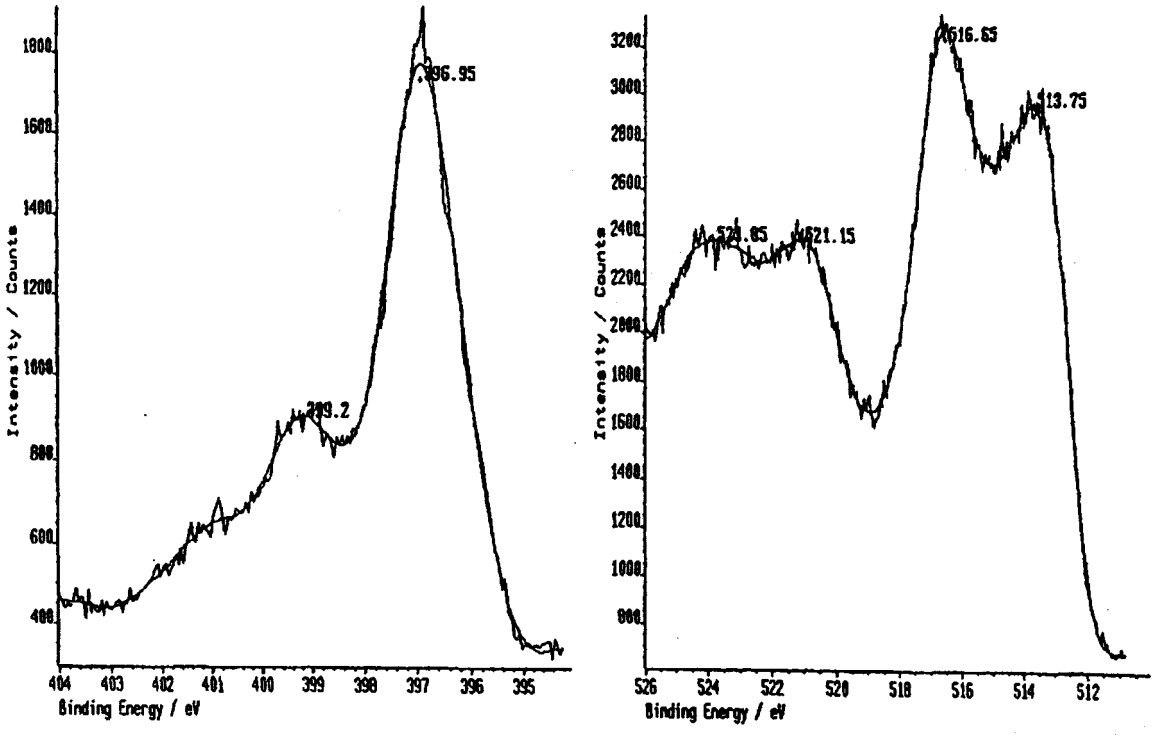

Fig .2a,2b

In cases of pressures close to the atmospheric lines of C (1s) also have been observed.

5. CONCLUSION

We showed that in NH_3 atmosphere under influence of UV laser pulses smooth vanadium nitride layers might have been grown on silicon surfaces with the thickness of 20-100 nm.

6. ACKNOWLEDGMENTS

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