CORROSION STUDY ON TiCrN (Titanium Chromide nickel) COATING ON MARTENSITIC STAINLESS STEEL GRADE 420.

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Abstract: **Abstract— This study investigates the corrosion resistance of TiCrN physical vapor deposition (PVD) coating on martensitic stainless steel AISI 420. Corrosion resistance is a critical property for materials used in various industries. The TiCrN coating has been recognized for its potential to enhance the corrosion resistance of stainless steels. Martensitic stainless steel AISI 420 is widely used but is known to be susceptible to corrosion. The experimental methodology involved depositing the TiCrN coating using PVD technique and subjecting the coated samples to corrosion testing, including salt spray tests and electrochemical techniques. The corrosion performance of the TiCrN-coated AISI 420 was compared with bare AISI 420.The results of the study demonstrated the effectiveness of the TiCrN coating in improving the corrosion resistance of AISI 420. The TiCrN-coated samples exhibited significantly reduced corrosion rates and higher pitting potentials compared to bare AISI 420. The enhanced corrosion resistance can be attributed to the barrier properties, passivation behavior, and chemical stability provided by the TiCrN coating. These findings suggest that TiCrN PVD coating has the potential to extend the service life and improve the performance of martensitic stainless steel AISI 420 in corrosive environments. Further applications of TiCrN coating in industries requiring corrosion-resistant materials can be explored. Future research should focus on optimizing the coating parameters and studying the long-term durability of the TiCrN-coated AISI 420.**

Keywords: corrosion resistance, TiCrN coating, physical vapor deposition, martensitic stainless steel AISI 420, corrosion testing.

I. INTRODUCTION

Corrosion resistance is a critical property for materials used in various industries, as it affects the durability and performance of components in corrosive environments. Martensitic stainless steel AISI 420 is widely utilized due to its high strength and wear resistance. However, AISI 420 is known to be susceptible to corrosion, which limits its applications in corrosive conditions. To enhance the corrosion resistance of AISI 420, surface coatings have been explored. Physical Vapor Deposition (PVD) coatings have gained attention for their ability to improve the corrosion resistance of stainless steels. Among various PVD coatings, TiCrN (Titanium Chromium Nitride) has shown promising results due to its excellent chemical stability, hardness, and barrier properties. This study focuses on investigating the corrosion resistance of TiCrN PVD coating on martensitic stainless steel AISI 420. By depositing TiCrN coating onto AISI 420 using PVD techniques, we aim to evaluate the effectiveness of this coating in improving the corrosion resistance of AISI 420. The study involves conducting corrosion tests, such as salt spray tests and electrochemical techniques, to assess the performance of TiCrN-coated AISI 420 in corrosive environments. The results of this research will provide valuable insights into the potential of TiCrN PVD coating as a means to enhance the corrosion resistance of

AISI 420. This knowledge can lead to the development of more durable and reliable materials for industries where corrosion resistance is crucial. The study employs corrosion testing methods, including salt spray tests to assess the performance of TiCrN-coated AISI 420 in corrosive environments. These tests allow for

II. Materials and Methods:

MATERIAL: Martensitic Stainless Steel Grade 420

Martensitic stainless steels are a group of stainless steels known for their high strength, hardness, and wear resistance. AISI 420 is a specific grade within the martensitic stainless steel family. It is characterized by its moderate corrosion resistance and excellent mechanical properties. AISI 420 contains a minimum of 12% chromium, which provides its corrosion resistance and enables it to form a protective oxide layer on the surface. Additionally, AISI 420 typically contains around 0.15% carbon, which contributes to its high hardness and strength. This stainless steel grade is known for its ability to be heat treated to achieve even higher hardness and wear resistance Strength and Hardness: AISI 420 exhibits high strength and hardness, making it suitable for applications that require resistance to mechanical wear, such as cutting tools and components subjected to high loads. Corrosion Resistance: While AISI 420 offers moderate corrosion resistance compared to other stainless steel grades, it is susceptible to corrosion in aggressive environments. Therefore, surface treatments like coatings are often applied to enhance its corrosion resistance. Machinability: AISI 420 is known for its good machinability, allowing for ease of fabrication and production of various components.

Tensile Strength: The tensile strength of AISI 420 is typically in the range of 600 to 1,200megapascals (MPa). Tensile strength measures the material's ability to withstand pulling or tensile forces before it deforms or breaks. Yield Strength: The yield strength of AISI 420 is generally around 350 to 700 MPa. Yield strength represents the stress level at which the material starts to deform plastically.

Hardness: AISI 420 exhibits high hardness levels. The typical hardness range for AISI 420 is between 45 and 53 on the Rockwell hardness scale (HRC). This hardness contributes to its wear resistance and suitability for cutting tools and components subjected to abrasion and mechanical stresses.

accelerated corrosion assessment, providing insights into the coating's ability to withstand corrosive conditions. Understanding the corrosion resistance of TiCrN PVD coating on AISI 420 is of great importance as it can lead to the development of more durable and reliable

Impact Resistance: Martensitic stainless steels like AISI 420 generally have lower impact resistance compared to austenitic or ferritic stainless steels. The impact resistance of AISI 420 depends on various factors such as heat treatment, microstructure, and the presence of notches or stress concentrations.

Ductility: AISI 420 exhibits limited ductility compared to some other stainless steel grades. It is a relatively hard and brittle material, which means it has reduced elongation and limited ability to deform without fracture. Fatigue Strength: The fatigue strength of AISI 420 is generally good due to its high hardness and strength. Fatigue strength refers to the material's ability to withstand repeated cyclic loading without failure. mechanical properties can vary depending on the specific heat treatment, microstructure, and processing conditions of AISI 420. Additionally, material performance can be further improved or modified through heat treatment processes such as tempering, quenching, or annealing. Proper selection and control of these processes are crucial to achieve desired mechanical properties for specific applications.

Sample Preparation Obtain martensitic stainless steel AISI 420 substrates in the desired form sheets Clean the substrates thoroughly to remove any contaminants or surface impurities that could affect the coating adhesion and corrosion performance Ensure that the substrates are properly dried before proceeding with the coating process.

TiCrN Coating Deposition Utilize the Physical Vapor Deposition (PVD) technique for applying the TiCrN coating onto the AISI 420 substrates. Setting the PVD equipment according to the manufacturer's instructions and process parameters.

Clean the coating chamber and ensure it is free from any residual particles or contaminants. Load the AISI 420 substrates into the coating chamber, ensuring proper spacing and arrangement to facilitate uniform coating deposition. Vacuum Chamber: This is the primary component of the PVD equipment and provides a controlled environment for the deposition process. The vacuum chamber is designed to create and maintain a low-pressure atmosphere, typically in the range of 10^-3 to 10^-9torr, to prevent contamination and enable efficient vapor deposition.

Deposition Sources Cathodic Arc Sources: Cathodic arc sources utilize a high-voltage electric arc discharge to vaporize the source material, which is typically in the form of a solid cathode target. The vaporized material is then deposited onto the substrate.

Substrate Holder: The substrate holder or fixture holds the substrate material in place within the vacuum chamber during the deposition process. It ensures proper positioning and stability of the substrate, allowing for uniform coating deposition.

Power Supplies: Power supplies provide electrical energy to the various components of the PVD system. These include high-voltage power supplies for arc sources or sputtering targets and filament power supplies for electron beam sources.

Vacuum System: A vacuum system is used to evacuate the chamber and create the desired low-pressure environment. It typically includes vacuum pumps, such as turbomolecular pumps or rotary vane pumps, to remove air and other gases from the chamber.

Process Control and Monitoring: PVD equipment often includes a control system and monitoring instruments to regulate and monitor various process parameters. These may include temperature, pressure, deposition rate, and coating thickness.

Film Characterization Tools: After deposition, film characterization tools such as surface profilometers, scanning electron microscopes (SEM), X-ray diffractometers (XRD), and spectroscopic techniques may be used to analyze the thickness, morphology, composition, and structure of the deposited coating.

III. Results and Discussions:

A. Hardness Test

The hardness of the coating is as shown in table1. The hardness of TiCrN was higher than TiN coating. The possible increase in hardness is due the fine grain structure and self-strengthening spin odal phase segregation mechanism. The relation between hardness and grain size is well realized by "Hall – Patch " model wherein the hardness increases with decrease in grain size down to tens of nanometers. Addition of silicon improves the density of grain structure. The strong interfacial bond between the amorphous and crystalline causes enhancement in strength and further prevents the movement of dislocation causing increase in oxidation and wear resistance [2 – 4, 8, 9]. The hardness obtained in the present work is comparable with ref. [10]. However, the values did not reach the super hardness state as in [2 – 4]. Table1. Hardness values of as deposited coatings Type of Coating Color Hardness (HV0.1) TiN Golden yellow 1835.42 TiCrN Light Gold 2545.26

B. Scanning Electron Microscopy

The following images show the SEM images of all the two coatings. TiN and TiCrN coating almost show a smooth morphology. TiN coating shows the presence of a small hair line crack. These cracks do not propagate during machining and is called "gargling effect" [11]. Some porous areas are also visible. Some micro particles can be observed on TiCrN coating which could have resulted from Ti micro particles dropping out after deposition process [12,13] There are no cracks at all in TiCrN coating hence the surface finish is smooth after coating.

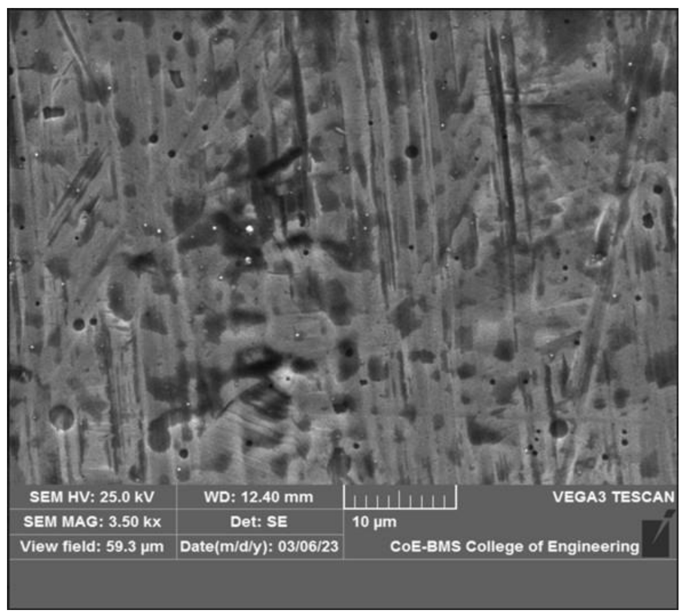


Fig 1 TiCrN SEM micrograph

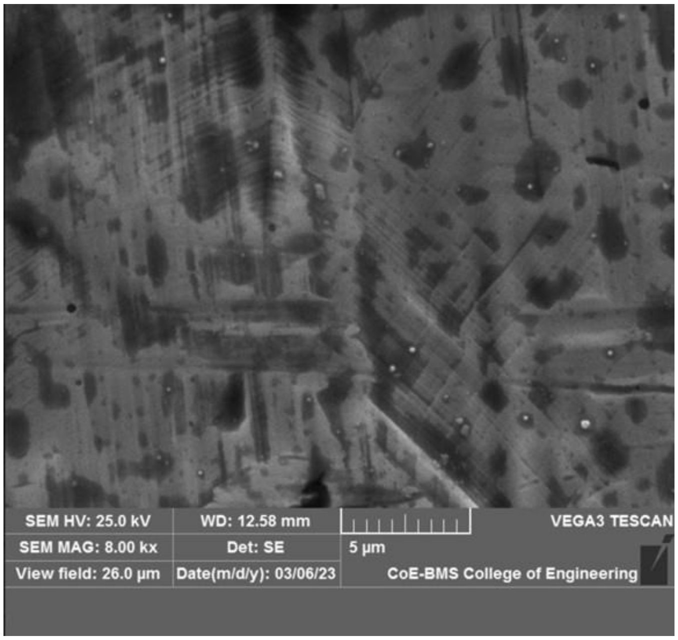


Fig 2 TiCrN SEM micrograph

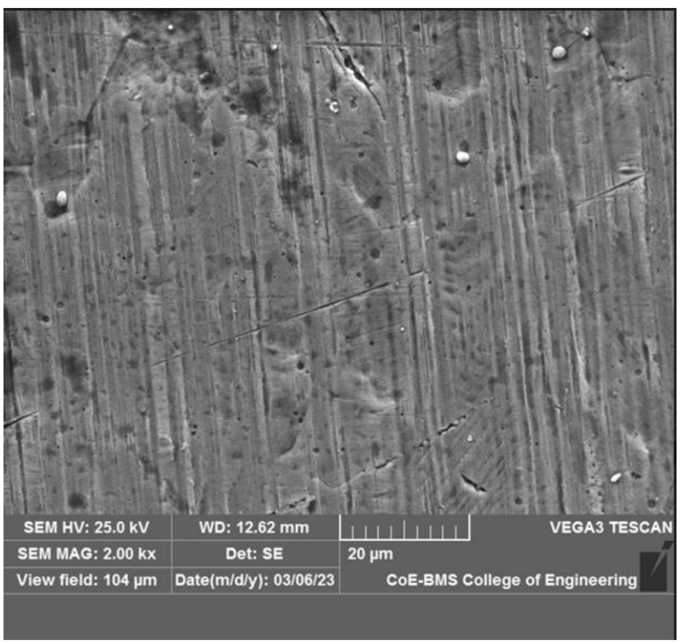
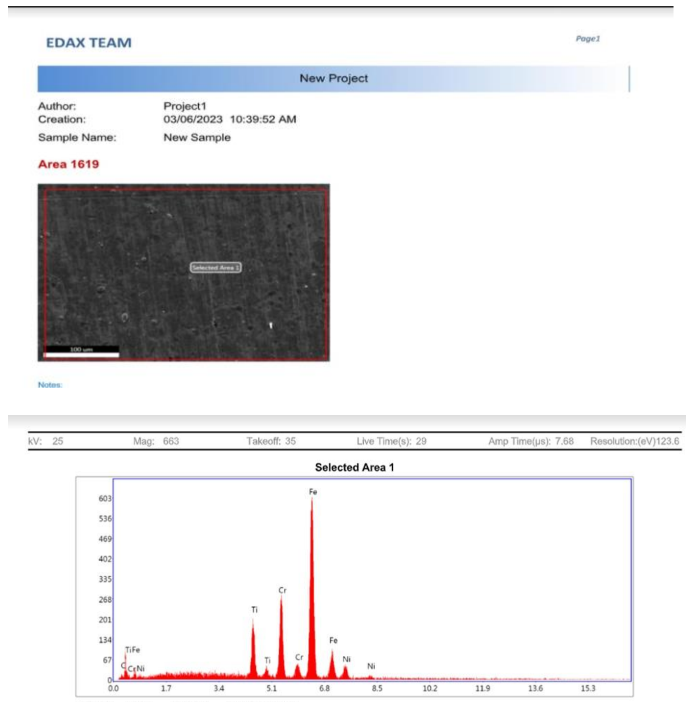


Fig 3 TiCrN SEM micrograph

B. Energy-dispersive X-ray analysis (EDAX)

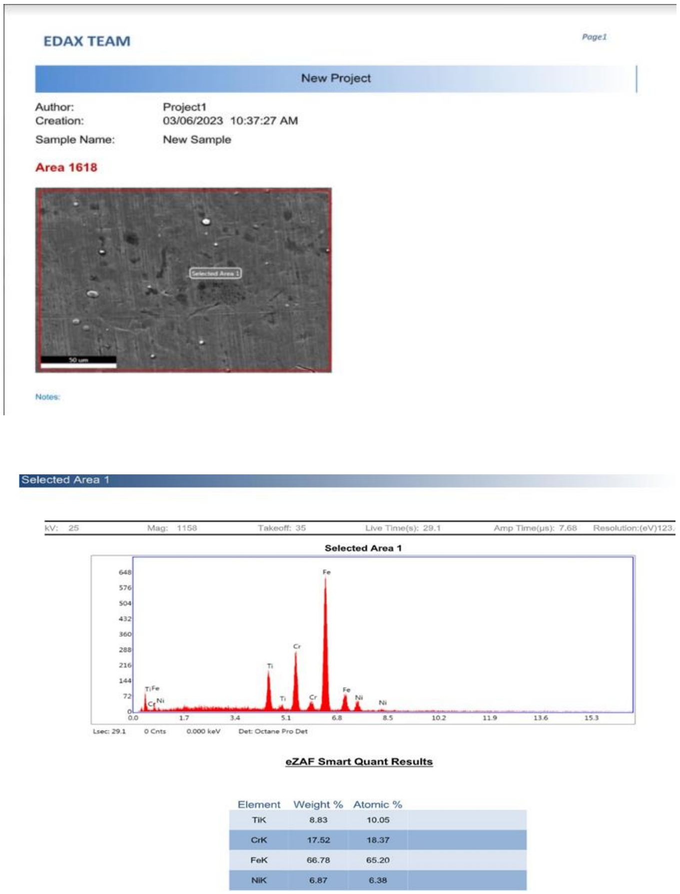
EDAX (Energy Dispersive X-ray Analysis) testing is a valuable tool for characterizing the elemental composition of materials. In the context of studying the corrosion resistance of TiCrN PVD coating on martensitic stainless steel AISI 420, EDAX can accurately determine the elemental composition of the coating and the underlying substrate. This information is crucial for understanding the coating's chemistry and its potential impact on corrosion resistance. It helps in assessing the presence and distribution of alloying elements, which can significantly influence the coating's performance EDAX analysis can detect any potential inter diffusion or diffusion of elements between the coating and substrate. It helps in evaluating the integrity of the coating-substrate interface and identifying any possible chemical reactions or undesired diffusion phenomena that may affect the corrosion resistance. EDAX testing complements the corrosion studies by providing valuable information about the elemental composition, interdiffusion, corrosion products, and coating uniformity. This knowledge contributes to a comprehensive understanding of the TiCrN PVD coating's corrosion resistance performance on martensitic stainless steel AISI 420, facilitating further improvements in coating design and optimization. EDAX can assess the uniformity of the coating composition across the sample surface. It helps in identifying any variations or inconsistencies in the coating's elemental distribution, which could affect its corrosion resistance properties.



eZAF Smart Quant Results

Element	Weight %	Atomic %
C K	6.72	24.64
TiK	8.38	7.70
CrK	16.52	13.99
FeK	62.20	49.03
NiK	6.17	4.63

Fig 4 TiCrN EDAX Analysis Area 1


EDAX TEAM

Page1

New Project

Author: Project1

Creation: 03/06/2023 10:37:27 AM

Sample Name: New Sample

Area 1618

Notes:

Selected Area 1

kV: 25 Mag: 1158 Takeoff: 35 Live Time(s): 29.1 Amp Time(µs): 7.68 Resolution:(eV)123.

Selected Area 1

Lsec: 29.1 0 Cnts 0.000 keV Det: Octane Pro Det

eZAF Smart Quant Results

Element	Weight %	Atomic %
TiK	8.83	10.05
CrK	17.52	18.37
FeK	66.78	65.20
NiK	6.87	6.38

Fig 4 TiCrN EDAX Analysis Area 2

C. Corrosion study by Salt spray test:

The salt spray test, also known as the salt fog test or ASTM B117 test, is a widely used method for assessing the corrosion resistance of materials and coatings. In the context of studying the corrosion resistance of TiCrN PVD coating on martensitic stainless steel AISI 420, the salt spray test creates a highly corrosive environment by exposing the coated samples to a continuous, controlled mist of saltwater solution. This accelerated testing method allows for the evaluation of the coating's performance in a relatively short period. It helps to simulate and predict the long-term corrosion behavior of the coated material in real-world conditions, the test period was done for 100hrs with 5% of NaCl and temperature during test period was maintained from 32-35°C, Air pressure to the chamber was maintained from 12-15 psi PH value of the solution was 6.9. 24hours: No significant changes in sample 48 hours: No significant changes in sample 72 hours: No significant changes in sample 96 hours: No significant changes in sample 100 hours: No significant changes in sample After 100 hours salt spray test there is no black, white patch, red rust and weight loss observed on the sample

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IV. CONCLUSION:

Physical vapor deposition is an effective method for depositing TiCrN coatings on stainless steel substrates. The process parameters, such as deposition temperature, deposition time, and gas composition, have a significant impact on the microstructure, morphology, and properties of the coatings.

There have been several research papers published on TiCrN coatings by physical vapor deposition, which have investigated the effects of different process parameters on the properties of the coatings. These studies have provided valuable insights into the deposition process and have helped to optimize the coatings' performance.

In summary, TiCrN coatings by physical vapor deposition offer great potential for enhancing the surface properties of stainless steel, and further research in this field is warranted to explore their full potential.

REFERENCES:

1. Manjeet Kumar a , Rajesh Kumar a, Sandeep Kumar b. "Coatings on orthopedic implants to overcome present problems and challenges: A focused review"
2. Department of Mechanical Engineering, UIET, Panjab University, Chandigarh, Chandigarh, UT, India
3. Department of Bio & Nanotechnology, Guru Jambheshwar University of Science and Technology, Hissar, Haryana, India
4. Anton Taran,1 Igor Garkusha,1 Valerij Taran,1 Renat Muratov,1 Vadym Starikov,2 Alexey Baturin,2 Tamara Skoblo,3 Svetlana Romaniuk3 and Athanasios G. Mamalis4, "Structure and properties of nanostructured ZrN coatings obtained by vacuum-arc evaporation using RF discharge.
5. Project center for nanotechnology and advanced engineering NCSR "Demokritos", Athens, Greece Technical University of Agriculture, Kharkov, Ukraine;
6. Ernan D. Mejía V, Aida M. Echavarría * Jorge Calderon, Gilberto Bejarano G, "Microstructural and electrochemical properties of TiAlN (Ag,Cu) nanocomposite coatings for medical applications deposited by dc magnetron sputtering
7. 1 Institute of Plasma Physics of NSC KIPT, Kharkov, Ukraine;
8. national Technical University "Kharkiv Polytechnic Institute", Kharkov, Ukraine; National