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Article

Hands-on Training Using a 3D PVD Vacuum Coating System: A Pre-Post Survey of Student Knowledge Improvement

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Abstrak

Dalam kegiatan ini, demonstrasi sistem PVD 3D dilaksanakan di Ming Chi University of Technology (MCUT) dengan melibatkan 10 peserta (n = 10) untuk meningkatkan pemahaman mereka mengenai teknologi pelapisan vakum. Melalui kegiatan praktik langsung, peserta memperoleh pengetahuan mengenai komponen sistem, persyaratan instalasi, sistem vakum, prosedur keselamatan, dan keseluruhan proses pengaturan sistem. Survei terstruktur untuk menilai pemahaman yang dilaporkan oleh peserta sendiri (self-reported understanding) dilakukan segera sebelum dan setelah demonstrasi. Rata-rata pemahaman yang dilaporkan sendiri meningkat dari 16,7% pada survei sebelum demonstrasi menjadi 93,3% pada survei setelah demonstrasi, yang menunjukkan peningkatan (knowledge gain) sebesar 76,6 poin persentase. Lebih dari 80% peserta melaporkan pemahaman yang komprehensif terhadap seluruh topik yang dievaluasi setelah kegiatan. Hasil ini menunjukkan bahwa demonstrasi tersebut berkaitan dengan peningkatan yang signifikan dalam pemahaman peserta yang dilaporkan sendiri mengenai teknologi PVD 3D.

KATA KUNCI

Deposisi uap fisik;
Deposisi lapisan;
Demonstrasi langsung

KEYWORDS
Physical vapor deposition;
Coating deposition;
Hands-on demonstration

Abstract

In this activity, a 3D PVD system demonstration was conducted at Ming Chi University of Technology (MCUT) for participants (n = 10) to improve their understanding of vacuum coating technology. Through hands-on activities, participants learned about system components, installation requirements, vacuum, safety procedures, and the overall system setup process. A structured survey assessing self-reported understanding was administered immediately before and after the demonstration. The average self-reported understanding increased from 16.7% in the pre-demonstration survey to 93.3% in the post-demonstration survey, corresponding to a knowledge gain of 76.6 percentage points. More than 80% of participants reported a comprehensive understanding of all evaluated topics after the activity. These findings suggest that the demonstration was associated with a substantial improvement in participants' self-reported understanding of 3D PVD technology.

1. INTRODUCTION

Various surface-coating technologies have been developed to improve the surface properties and service performance of engineering materials, including anodizing (Hao & Cheng, 2000; Lee et al., 2022), atomic layer deposition (ALD) (Dasgupta et al., 2016; Hu et al., 2017), chemical vapor deposition (CVD) (Eskildsen et al., 1999; Rebenne & Bhat, 1994), electroplating (Giurlani et al., 2018; Rashidi & Amadeh, 2010), and physical vapor deposition (PVD) (Bienk et al., 1995; Hajizadeh et al., 2026). Among these technologies, PVD has attracted considerable attention because it enables the deposition of thin, dense, and strongly adherent coatings with controlled composition and microstructure while generally operating at lower processing temperatures than many conventional coating techniques (Ataş Bakdemir et al., 2026; Kelly & Arnell, 2000; Sofronov et al., 2026). PVD coatings have been widely applied to improve wear resistance, corrosion resistance, and thermal stability across various industrial sectors (Baptista et al., 2018; Panjan et al., 2020). These characteristics make PVD coatings suitable for demanding service environments, including applications involving civil engineering materials such as steel structures and construction components.

Despite the growing importance of thin-film and surface-engineering technologies, students, educators, and early-career researchers may have limited opportunities to interact directly with advanced PVD equipment and observe the full coating fabrication process. In particular, understanding vacuum-system components, cooling requirements, operating procedures, safety considerations, and deposition-parameter control requires exposure to practical equipment that may not be readily available in conventional classroom settings. This training required a community-service demonstration at Ming Chi University of Technology (MCUT), involving 10 participants who were introduced to the operation and basic principles of a 3D PVD system.

The activity was designed to address this practical learning gap through direct demonstration and hands-on interaction with the equipment. Participants were introduced to the major components of the 3D PVD system, installation requirements, vacuum and cooling systems, safety procedures, system setup, and basic coating-deposition processes. The activity emphasized operational awareness and recognition of safe operating procedures rather than claiming to establish independent practical competence in PVD operation.

Therefore, the primary objective of this activity was to provide participants with practical exposure to 3D PVD technology and to improve their self-reported understanding of vacuum-coating principles, system components, operational requirements, and safety procedures. Specifically, the activity aimed to: (1) introduce the fundamental principles of vacuum deposition; (2) familiarize participants with the major components and operating requirements of a 3D PVD system; (3) increase awareness of appropriate safety procedures during vacuum-coating operations; and (4) improve participants' self-reported understanding of coating fabrication and the potential application of protective coatings for corrosion prevention. The effectiveness of the activity was evaluated using a structured pre- and post-demonstration survey of self-reported understanding.

2. METHODS

A demonstration of a 3D-Physical Vapor Deposition (3D-PVD) system installation and operation was conducted at the Center for Plasma and Thin Film Technology (CPTFT). The demonstration covered the major components of the 3D-PVD system, including the vacuum chamber, vacuum pumps, power supply, cooling system, target assembly, and safety features. Participants were provided with a step-by-step explanation of the installation procedure, system configuration, operational requirements, and safety precautions. In addition, hands-on activities were incorporated to allow participants to observe and interact with the equipment directly.

To evaluate the effectiveness of the demonstration, pre- and post-demonstration surveys were administered to 10 participants. The pre-demonstration survey was designed to assess initial knowledge of 3D-PVD system installation, including installation requirements, vacuum pump functions, electrical and cooling systems, safety considerations, and familiarity with system components. Following the demonstration, participants completed a post-demonstration survey to evaluate their understanding of the installation procedure, system operation, equipment components, maintenance requirements, and overall setup process.

Participant understanding was quantified using the percentage of positive responses. The understanding percentage was calculated according to **Eq. (1)**, where the number of participants indicating an understanding of a given topic was divided by the total number of participants and multiplied by 100.

$$Understanding\ (\%) = \frac{Number\ of\ participants\ who\ understand}{Total\ number\ of\ participants} \times 100 \qquad \textbf{Eq.1}$$

The effectiveness of the demonstration was further evaluated by comparing the average understanding levels obtained from the pre-demonstration and post-demonstration surveys. Knowledge gain was determined using **Eq. (2)**, which represents the difference between the post-demonstration and pre-demonstration understanding levels.

$$Knowledge\ gain\ (\%) = Post\ understanding\ (\%) - Pre\ understanding\ (\%) \qquad \textbf{Eq.2}$$

The survey results were analyzed using descriptive statistics and presented as percentages to illustrate the improvement in participant knowledge and awareness of 3D-PVD system installation and operation.

3. RESULT AND DISCUSSION

This demonstration was conducted at the Ming Chi University of Technology, Taiwan. The activity involved 10 participants working on thin film-related research. **Fig.1** illustrates the demonstration of the Vacuum 3D PVD system with a total of 10 participants.

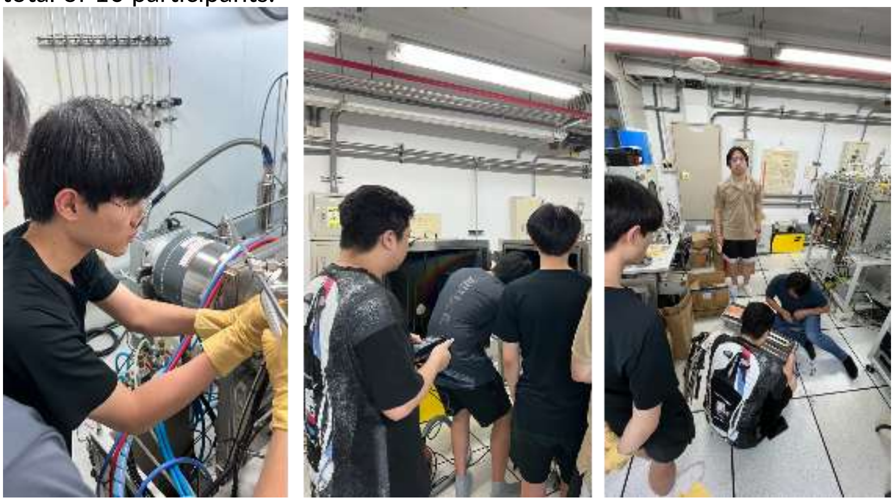

Figure 1. Activity during the demonstration of the 3D PVD system.

During the demonstration focused on introducing the operational principles of the vacuum deposition system, including chamber preparation, vacuum pumping procedures, and basic process control. Participants were guided through the main components of the system and their functions, enabling them to understand the relationship between deposition parameters and thin-film growth behavior.

Figure 2 presents a detailed view of the 3DPVD vacuum chamber and TiZrNbTaFe (HEA) target. The chamber has dimensions of 660 mm × 600 mm (LJ-UHV Technology Co., Ltd., Taiwan) and is equipped with four target holders with dimensions of 304.8 × 127 × 6 mm. The target refers to the source material used for deposition, such as Ti, Cr, Nb, or other elements, including high-entropy alloys (HEAs) composed of five or more elements.

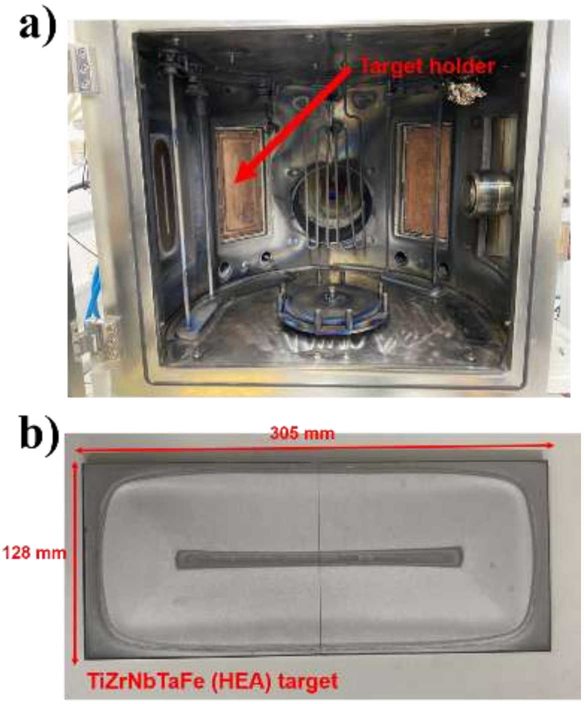

Figure 2. a) View of 3DPVD vacuum chamber and b) TiZrNbTaFe (HEA) target

Table 1 presents the results of the pre-demonstration and post-demonstration surveys on 3D-PVD system installation knowledge (n = 10). The level of understanding was calculated using **Eq. (1)**. Before the demonstration, most participants had limited knowledge of 3D-PVD system installation, as indicated by the low understanding percentages for all survey questions. In particular, none of the participants were familiar with the main system components or the overall setup process, while only 10-40% demonstrated an understanding of installation requirements, vacuum pump functions, electrical and cooling systems, and safety considerations.

Table 1. Results of the pre-demonstration and post-demonstration surveys on 3D-PVD system installation knowledge (n = 10)

Question		Installation requirements	Importance of vacuum pumps	Electrical and cooling requirements	Safety considerations	Familiarity with main components	Overall setup process
Pre-demonstration survey	**Understand (%)**	30	40	20	10	0	0
	Do Not Understand (%)	70	60	80	90	100	100
Post-demonstration survey	**Understand (%)**	80	90	100	100	100	90
	Do Not Understand (%)	20	10	0	0	0	10

Following the demonstration, a substantial improvement in participant knowledge was observed, as quantified using **Eq. (2)**. More than 80% of participants demonstrated an understanding of all evaluated topics, with several categories achieving 100% comprehension. The average understanding level increased from 16.7% before the demonstration to 93.3% after the demonstration, corresponding to a knowledge gain of 76.6%, as shown in **Fig. 3**. The results indicate that the 3D-PVD demonstration was highly effective in enhancing participants' knowledge of system installation requirements, equipment components, vacuum and cooling systems, safety procedures, and the overall setup process. It should be noted that the reported knowledge gain is based on self-reported understanding in this report.

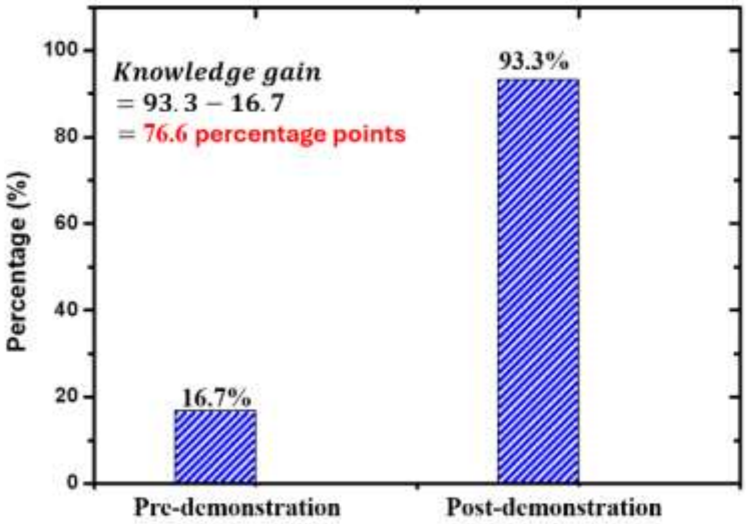

Figure 3. Pre-demonstration and post-demonstration participant understanding and the resulting knowledge gain for 3D-PVD system installation (n = 10).

4. CONCLUSION

A 3D-PVD system installation and operation demonstration was successfully conducted at Ming Chi University of Technology (MCUT) to provide participants with practical exposure to vacuum coating technology. Through hands-on activities, participants were introduced to system components, installation requirements, vacuum and cooling systems, safety procedures, and the overall system setup process. Based on the pre- and post-demonstration survey, the average knowledge gain (self-reported understanding) increased from 16.7% before the demonstration to 93.3% after the activity, corresponding to an increase of 76.6 percentage points. More than 80% of participants reported an understanding of all evaluated topics after the demonstration. These findings indicate a substantial immediate improvement in participants' self-reported understanding and operational awareness of the 3D-PVD system. However, because the evaluation relied on self-reported responses collected immediately before and after the activity, the findings do not establish improvements in objectively measured practical competence, participant engagement, long-term knowledge retention, or broader educational effectiveness. Further evaluation using objective knowledge or skills assessments and longitudinal follow-up would be required to determine these outcomes.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Ataş Bakdemir, S., Özkan, D., Arpacı, K. A., Türküz, C., Konar, M., & Sulukan, E. (2026). Advanced tribological performance of PVD AlTiCrN and TiCrN coatings under dry and lubricated conditions. *Wear*, *591*(January), 206586. https://doi.org/10.1016/j.wear.2026.206586

Baptista, A., Silva, F., Porteiro, J., Míguez, J., & Pinto, G. (2018). Sputtering Physical Vapour Deposition (PVD) Coatings: A Critical Review on Process Improvement and Market Trend Demands. *Coatings*, *8*(11), 402. https://doi.org/10.3390/coatings8110402

Bienk, E. J., Reitz, H., & Mikkelsen, N. J. (1995). Wear and friction properties of hard PVD coatings. *Surface & Coatings Technology*, *77*, 475–480.

Dasgupta, N. P., Lee, H.-B.-R., Bent, S. F., & Weiss, P. S. (2016). Recent Advances in Atomic Layer Deposition. *Chemistry of Materials*, *28*(7), 1943–1947. https://doi.org/10.1021/acs.chemmater.6b00673

Eskildsen, S. S., Mathiasen, C., & Foss, M. (1999). Plasma CVD: process capabilities and economic aspects. *Surface and Coatings Technology*, *116–119*, 18–24. https://doi.org/10.1016/S0257-8972(99)00142-5

Giurlani, W., Zangari, G., Gambinossi, F., Passaponti, M., Salvietti, E., Di Benedetto, F., Caporali, S., & Innocenti, M. (2018). Electroplating for Decorative Applications: Recent Trends in Research and Development. *Coatings*, *8*(8), 260. https://doi.org/10.3390/coatings8080260

Hajizadeh, R., Rahimi, M., & Dehghani, K. (2026). The effect of NiCrN coating by Arc-PVD method on the corrosion behavior and hydrophobicity of the low-density AlCrFeMnTi high entropy alloy. *Journal of Materials Research and Technology*, *41*(January), 3968–3979. https://doi.org/10.1016/j.jmrt.2026.02.046

Hao, L., & Cheng, B. R. (2000). Sealing processes of anodic coatings—Past, present, and future. *Metal Finishing*, *98*(12), 8–18. https://doi.org/10.1016/S0026-0576(01)80002-7

Hu, L., Qi, W., & Li, Y. (2017). Coating strategies for atomic layer deposition. *Nanotechnology Reviews*, *6*(6), 527–547. https://doi.org/10.1515/ntrev-2017-0149

Kelly, P. J., & Arnell, R. D. (2000). Magnetron sputtering: a review of recent developments and applications. *Vacuum*, *56*(3), 159–172. https://doi.org/10.1016/S0042-207X(99)00189-X

Lee, C.-C., Chen, C.-W., Lin, J.-S., Wang, S. H., Lee, C.-S., Chen, C.-C., Lin, Y.-H., & Chen, C.-Y. (2022). Effect of Anodization Treatment on the Thickness, Hardness, and Microstructural Characterization of Anodic Aluminum Oxide Film on AA 6061 and Critical Patent Analysis. *Journal of Materials Engineering and Performance*, *31*(1), 667–681. https://doi.org/10.1007/s11665-021-06205-1

Panjan, P., Drnovšek, A., Gselman, P., Čekada, M., & Panjan, M. (2020). Review of Growth Defects in Thin Films Prepared by PVD Techniques. *Coatings*, *10*(5), 447. https://doi.org/10.3390/coatings10050447

Rashidi, A. M., & Amadeh, A. (2010). Effect of Electroplating Parameters on Microstructure of Nanocrystalline Nickel Coatings. *Journal of Materials Science & Technology*, *26*(1), 82–86. https://doi.org/10.1016/S1005-0302(10)60013-8

Rebenne, H. E., & Bhat, D. G. (1994). Review of CVD TiN coatings for wear-resistant applications: deposition processes, properties and performance. *Surface and Coatings Technology*, *63*(1–2), 1–13. https://doi.org/10.1016/S0257-8972(05)80002-7

Sofronov, Y., Dochev, B., Mishev, V., Nikolov, A., Petrov, K., Dimitrova, R., Yordanov, M., Angelov, M., Todorov, G., & Marchev, K. (2026). Investigation of the Mechanical Properties and Friction Coefficient of Cr/CrTiAl and Cr/(CrTiAl)N/CrTiAl PVD Coatings Deposited on 42CrMo4 QT Steel. *Metals*, *16*(2), 231. https://doi.org/10.3390/met16020231