Project-Based Nanotechnology Learning: A Lab Activity Study of a Thin-Film Module

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Introduction

The laboratory activities used for thin film deposition in nanotechnology courses are an important academic setting for engineering students and provide in-depth training in project-based learning, so most graduate students majoring in science/engineering must conduct experiments in a laboratory. The implementation of experience by experimentation favors the introduction of thin-film deposited modules in nanotechnology and plays an important role in project-based learning. Of these, the development of a thin-film deposited module in nanotechnology course using experimental instruments such as magnetron sputtering modules in a laboratory allows a significant number of practical activities, wherein students can verify and practice analytical concepts and methods learned in theoretical courses, in project-based learning. The thin film deposition project integrates the fundamental elements of mechanical, electrical, engineering and material fabrication systems, culminating in a powerful, adaptable, interdisciplinary approach to nanotechnology.[1-4] This project has a laboratory component, where students fabricate nanosystems/devices in hands-on experiments using sputtering systems, actuators and data collection and control tools that allow for multiple solutions to be given experimental problems in nanotechnology. The thin-film modules have developed in the manufacturing and material courses, such as design, process, analysis and product modules, which are a typical nanotechnology project, were presented by several authors.[5-8] They showed how the laboratory facilities, the design/automation of physical vapor deposition, and the thin-film modules in nanotechnology courses in engineering education, where can be effectively integrated to teach some nanoscale courses with appropriate hands-on experience. This study develops a hands-on magnetron sputtering system for use in the thin-film modules in an undergraduate course, which offers hands-on experience in the laboratory for students.

Method and Design

Table 1 Design of integrated curriculum for implementing the thin films for use in sputtering deposition modules for teaching and learning of nanotechnology projects

Course	Period	Lecturing contents	Experimental tasks	Covered issues	Student activities	Learning goal	Note
Thin-film design module	3 weeks	Power, cooling, chamber, target, control, vacuum system	Assembly, programs and assignment	Design	Operation Proficiency Learning by doing	Strengthening of their self-directed learning abilities Active participation	Training problem-based directed to the acquisition of knowledge.
Thin-film fabricated module	5 weeks	Thin film, nanoparticle, nano-synthesis, nano-characterization	Fabrications of ZrN, CrN and DLC films	Process	Collaboratively Conducted project Laboratory management	Engages students in a team Cooperative manner to learning and resolve certain problem	Active learning, student centered practical experience develop motivation and organization skills
Thin-film product module	3 weeks	Hard thin , ceramic, multilayer and decorative films	Examples of ZrN, CrN and DLC films	Artifact	Artifacts to create Problem-solving abilities	Motivation Function performance	Results sharing more student-centered directed to the application of knowledge
Thin-film analysis module	7 weeks	Atomic force and scanning electronic microscopes, X-ray diffractometer, and scratch tester	Surface Morphology Structure, adhesive force and composition measurement	Analysis	Developing authentic examined skills	Examination and performance tested	Skills development and motivation abilities
Evaluation and survey module	1 week	Curriculum, teaching and learning method, competence	Report Oral Review	Achieve-ment	Feedback to enhance teaching management and justify teaching quality and assess learner achievement	Assessment Reflection Evaluation	Skills in human relations as well as technical competence

Results

Table 2 t-Test for the expert and scores of student survey in the questionnaire.

No.	Survey Questions	Students				Experts		t-Test
		Pre survey (n=28)		Post survey (n=28)		Survey (n=10)		
		M	SD	M	SD	M	SD	
1	The guide of the thin-film deposited modules was complete and clear	3.78	0.417	4.14	0.448	4.50	0.413	2.283[a]
2	The operating guide of the thin-film deposited module was easy to understand	3.14	0.591	4.28	0.599	5.00	0	3.704[b]
3	The nucleation, growth, and coalescence in the thin-film deposited module were clear	2.96	0.838	3.28	0.658	4.50	0.316	9.401[b]
4	The thin-film deposited modules in engineering undergraduate courses were suitable for students	3.64	0.558	4.32	0.547	4.40	0.522	0.396
5	The thin-film deposited modules were helped for the student learning of lab activities in nanotechnology courses	4.25	0.441	4.75	0.518	4.70	0.312	0.420
6	The courses of thin-film modules were more interesting than that of the traditional textbook	4.57	0.572	4.42	0.503	4.87	0.152	5.291[b]
7	The nanotechnology courses were well designed and processed	3.71	0.534	4.61	0.497	4.60	0.356	0.042
8	The processes for the thin-film deposited modules were helpful to students' learning	4.36	0.558	4.78	0.417	4.81	0.546	0.228
9	The artifacts of thin-film modules were appropriate for nanotechnology learning	4.39	0.566	4.17	0.475	4.32	0.472	0.571
10	The properties of thin films were completely examined in the analysis such as SEM,XRD and XPS	2.57	0.572	3.82	0.611	4.26	0.324	1.771
11	Analysis in the thin-film modules was understood and sufficient	2.96	0.507	3.46	0.507	4.50	0.472	3.531[b]
12	The AFM, SEM, XPS examination of the thin-film modules were understood and clear	3.86	0.448	4.35	0.558	4.77	0.224	3.794[b]
13	The thin-film deposited modules foster problem-solving skills and enhance project-based nanotechnology learning future	4.67	0.475	4.85	0.356	4.78	0.122	1.163

Table 3 the assessment scores of teacher and peer for the joined students after the project-based thin-film learning

	Score	1 50～60	2 60～70	3 70～80	4 80～90	5 90～100	Mean	Standard deviation
Teacher assessment	Number	1	2	12	10	3	3.43	0.92
	percentage	3.6	7.1	42.9	35.7	10.7		
Peer assessment	Number	1	2	5	16	4	3.71	0.94
	percentage	3.6	7.1	17.9	57.1	14.3		

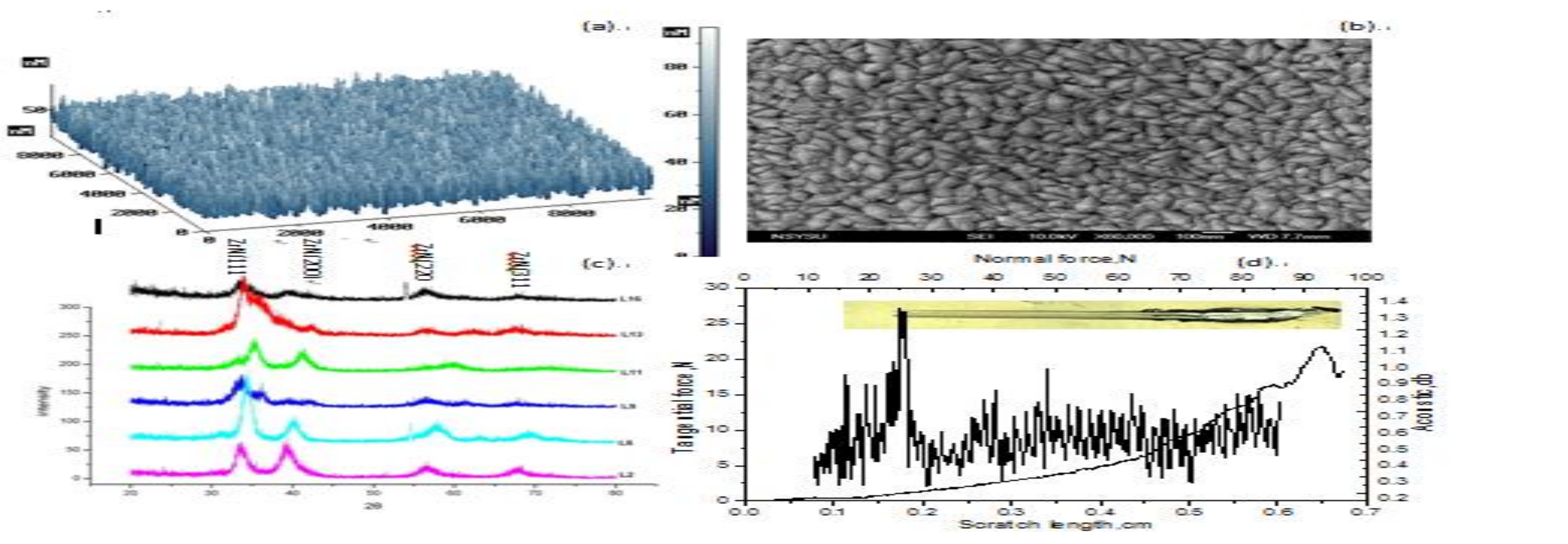

Fig. 1 Sample of the thin-film project that is provided by the participation of undergraduate students; (a) AFM surface topography of ZrN films, (b) SEM surface texture of ZrN films, (c) XRD pattern of ZrN films and (d)Scratched micrograph of ZrN films.

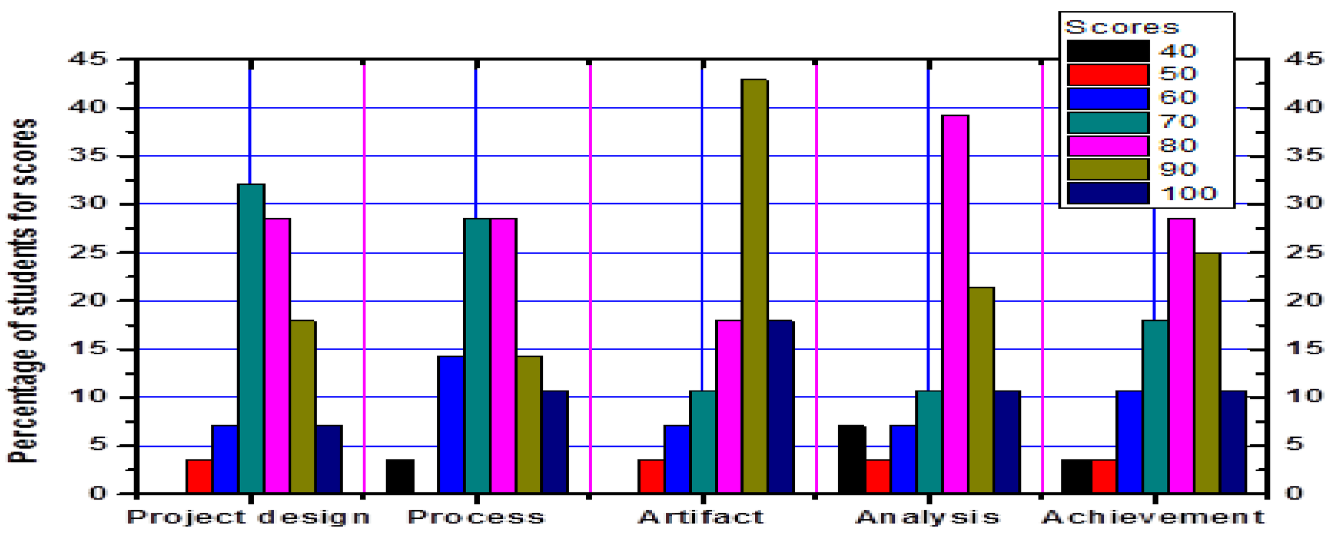

Fig.2 Distributions of student scores for analytic rubrics in project-based learning

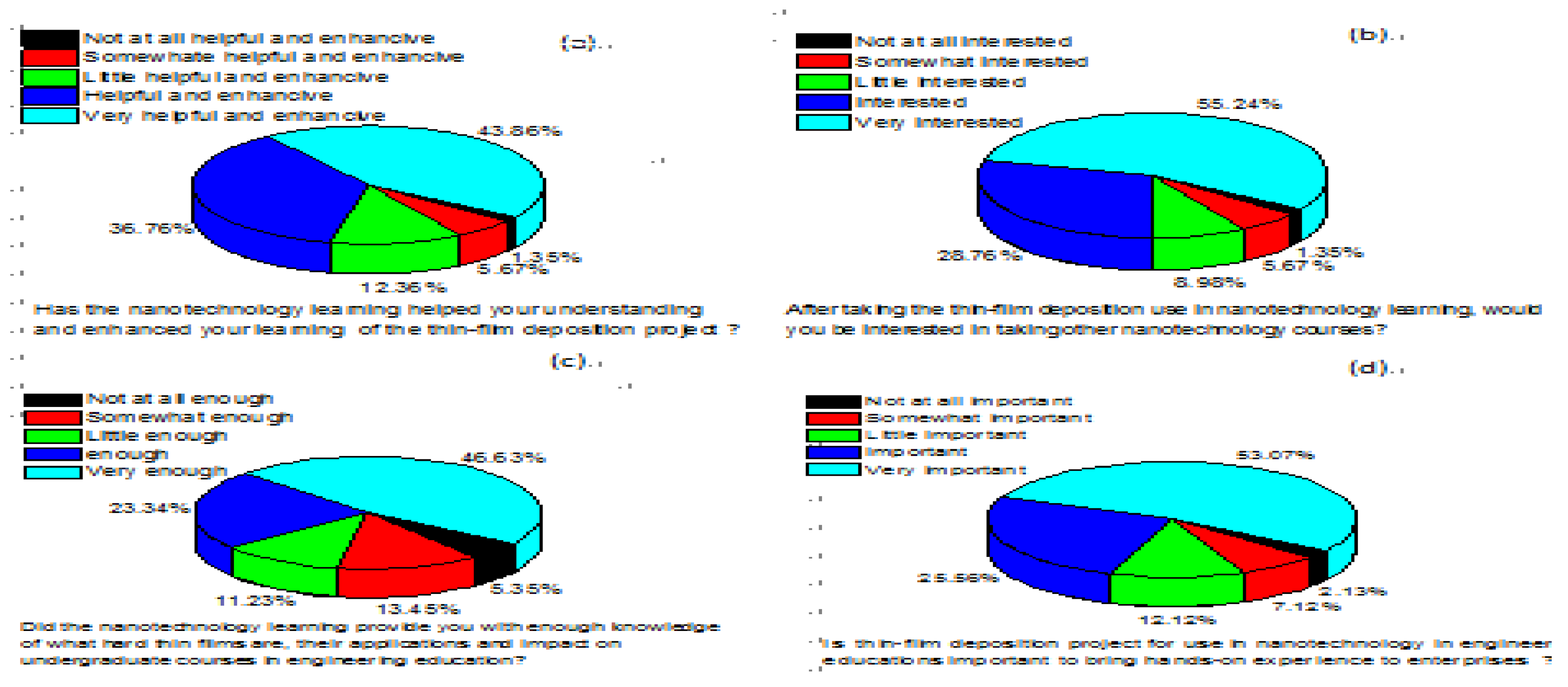

Fig. 3 The reflected assessment of students on project-based nanotechnology learning after the project

Conclusions

This study developed the thin-film modules for the use of the project-based nanotechnology learning in engineering education. The proposed project could be introduced to nanotechnology curricula by incorporating project-based learning in the lab activity, mentoring undergraduate students in nanotechnology research, and introducing a thin-film module. In addition, the thin-film modules give students a comprehensive background in the art and science of engineering to leverage an existing graduate program in the project-based nanotechnology learning. Most scores on the questionnaire survey, with the mean scores and deviations, that display the evaluations made by the two groups are exactly alike, displaying high consensus. In addition, a survey shows that most students have completed the nanotechnology course in the thin film module, which can promote nanotechnology learning in the future. Besides, more than 70% of the students found the use of the thin-film modules for fulfilling project-based nanotechnology learning to be helpful, strengthening and interesting. Preliminary evaluation of the laboratory platform was encouraging and showed it is successful in helping students understand nanotechnology concepts and the applications of the thin-film modules. According to the results, we discovered students rely on their hands-on experiences in the thin-film modules developing the project-based learning, not only to learn the basics but also to incorporate the thin-film modules to nanotechnology courses in engineering education. Thus, the project could mentor undergraduate students to lab activity in the thin-film modules and also lead a hands-on into nanotechnology courses in project-based learning.

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