Core Competencies for Technicians Working in Nanotechnology
National Resource Center for Materials Technology Education
Edmonds Community College, Lynnwood, WA
November 2010

Copyright Edmonds Community College 2009
This material may be used and reproduced for educational purposes only.

Introduction

Core competencies in nanotechnology relate to the fundamental set of abilities and understanding of basic workplace skills, chemical and physical science, processing, techniques and material behavior needed by technicians who work with nanotechnology in research, development and device production. The goal of this core competency study is to determine the areas of greatest importance for educational training for these technicians. This will provide guidance for faculty and other educational providers as educational programs and curricula are developed in this area.

These competencies were determined using a survey of professionals working both in research and in applications of nanotechnology. Data were collected over six months in late 2009 and early 2010. Survey responses were obtained from 39 professionals working in this area, with technical questions being answered by between 22 and 30 respondents, the smaller numbers being for the latter questions in the survey. About 200 requests for survey response were issued, resulting in an overall response rate of over 19% and a technical question response rate of between 11 and 15%. Details on respondents' backgrounds are given in Table I. Despite the small number of respondents, the breadth of interests and applications of the respondents provides a reasonable cross section of the industry today. Therefore, the results are considered helpful in the development of curriculum and programs for technicians working in nanotechnology.

The survey was developed by the National Resource Center in Materials Technology Education (MatEd) as an extension of its original core competency study in materials, and in collaboration with North Seattle Community College. This report presents the overall data set, looking at what technicians need to know and the relative importance of each requirement.

This report first discusses the important applied chemical and physical science skills needed by technicians in nanotechnology, and then focuses on specific competencies related to processes and techniques. Also included for reference are basic workplace skills for technicians from an earlier study focused on the more traditional aspects of Materials Science and Technology. 

Applied Chemical and Physical Science Skills

Basic skills in chemistry, physics, materials science and related areas are reported in Table II. In this portion of the survey, respondents were asked to indicate the importance of each of 48 specific skills, with ratings from 1,"vital," to 4,"relatively unimportant." Here, rating values are presented as averages across all values noted by the indicated set of respondents. Reported average rating values from 1 to 1.4 should be considered "vital," while those from 1.5 to 2.4 should be considered "relatively important."
Since these are average responses from between 28 and 30 respondents, it seems significant that the 83% of these average values are in fact in the "vital" or "relatively important" categories. In MatEd's earlier study focused on the more traditional aspects of Materials Science and Technology, similar skills were also regarded as "vital" or "relatively important." The additional information in the current study further validates the earlier study in demonstrating that these applied chemical, physical and materials science competencies are essential in technician education in a wide variety of areas related to materials science and technology, nanotechnology included.

Of specific interest in the prior survey were the effects of processing and manufacturing variables on resultant materials properties of the product, rated "vital." In this survey, one respondent noted that a technician needs to understand the effect that processing parameters in one process might have on processes that follow. This extends the original finding and suggests the need for a technician to understand not only his/her specific process, but also prior and subsequent processes to ensure quality in the product. Other respondents noted the importance of technicians understanding schematics of their processing equipment and to be able to take full responsibility for the system, including their repair; this also can relate to subsequent processes and overall quality in the product.

Relative Importance of Processes and Techniques

This survey also determined the importance of a series of processes and techniques commonly in nanotechnology. As nanotechnology is a developing field, and since professionals who work in nanotechnology have applications interests in a wide area from materials to medical processes and devices, it was important to determine which processes and techniques were important to survey. To carry this out, we did a test survey with a limited sampling in which we asked about relative importance of a variety of techniques, including techniques identified in a related study by the Southwest Center for Microsystems Technologies (SCME), which issued two limited reports focused on MEMS competencies in 2009. From this test survey, we identified our listing of techniques to be studied in this survey.

We then asked respondents to indicate the important each of 20 processes to the nanotech field. Questions were divided into the areas of materials and device processing, synthesis techniques, and analysis methods. The results of this portion of the survey are given in Table III, where the rating numbers, using the same scale as in Table II, are averages over all responses.

In the area of materials and device processing, the processes rated most important for technicians are seen to be photolithography, plasma etching and wet chemical etching. In fact, photolithography, rated the most importantly technique, was called vital by 10 respondents and relatively important by 11. For wet chemical etching, 8 rated it vital and 13 relatively important; for plasma etching, these numbers were 7 and 10. These are clearly focus areas for technician education.

In terms of nanoscale synthesis processes, each area listed averaged in the relatively important area. Specifically, each of these areas had between 10 and 13 responses in the relatively important area, with vital being the response from 10 raters for thin film deposition, and 6 for CVD.
Focusing on analytical techniques, all on the list except gas adsorption averaged in the relatively important area, with electron microscopy, optical spectroscopy, surface analysis and optical and laser analysis leading the responses. Clearly, these and related techniques are highly important for technicians who work with nanotechnology R and D, processes and devices.

**Needed technician knowledge regarding each system**

Using these data, the survey then looked at specific skills related to each of the processes or methods noted above. Table IV shows the percentage of individual respondent responses indicating the most important actions that a technician needs to be able to take relative to each system. That is, do they need to be able to operate the system or just understand how it works; or do they need to explain the data and design experiments use the system?

The results indicate that the majority of respondents indicate that operational ability is most important for photolithography, wet chemical etching, PVD, optical and laser analysis, optical and electron spectroscopy, surface analysis and SEM. These results, shown in bold in Table IV, may not hold for all applications or all technicians, but may be important educational and training focal areas for many technicians in this area. From the breadth of responses, the results may also reinforce the need for technicians to have detailed knowledge the relevant overall production process and, from the prior section, may also need to be able to repair the system and understand its effects on subsequent steps in the process involved.

**General competencies needed by all technicians**

This survey omitted questions relating to general competencies for technicians in areas such as workplace skills, mathematics and computers. These competencies have been surveyed in MatEd's earlier study, noted earlier.\textsuperscript{1,2} For reference, these results are repeated in Table V, with results presented in rounded numbers on the same scale as is used in much of this report. Specific areas here include communications skills, measurement, lab skills, applied mathematics, computer skills and professionalism. It should be noted that all of these "softer" skills are rated as highly if not of greater importance than the more technical competencies discussed earlier.

**Observations and Conclusions**

Looking at the overall results, it is clear from this survey, as it was in MatEd's prior survey\textsuperscript{1,2} that general skills are most important for technician education. This includes basic workplace skills, mathematics and computer usage, along with basic chemical and physical science knowledge.

For technical education programs focused on nanotechnology, the survey identifies the needed capabilities to understand and operate specific systems, processes and analytical techniques. Respondents rated some of these latter areas quite highly, indicating their specific importance. Many of these techniques are important as well as MEMS and in semiconductor processing, indicating potential overlap with education in those areas.

These competency ratings were developed with representation from a broad set of professions working currently in the nanotechnology area. However, due to the small sample size and the rapid evolution of this set of technologies, this set of competencies cannot be considered complete. It is also the case that some lower rated competencies can be quite important in certain specialty areas that were not represented. From this point of view, the study provides a
starting point for the determination of basic competencies that are essential in nanotechnology technician education. MatEd welcomes further elaboration on competencies in the materials area.

Acknowledgments

The MatEd team wishes to thank Alissa Agnello of North Seattle Community College for her assistance in developing the test survey. Prof. G.Z.Cao of the University of Washington and Ms. Agnello assisted in identifying potential respondents. MatEd also wishes to thank Robert Ehrmann, Deborah Newberry, Tom McGlew and David Hata for assisting in distribution of the survey and reviewing the draft report. This work is part of a larger project funded by Advanced Technology Education Program of the National Science Foundation, DUE 0501475 and DUE 0903112.

References

1. National Resource Center for Materials Technology Education (MatEd), Edmonds Community College, Lynnwood, WA; www.materialseducation.org; MatEd@edcc.edu


3. The full set of competency listings with background is provided at http://www.materialseducation.org/educators/competencies/
