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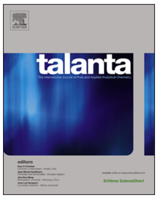

Review

Roles of chemical metrology in electronics industry and associated environment in Korea: A tutorial

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ABSTRACT

Chemical metrology is gaining importance in electronics industry that manufactures semiconductors, electronic displays, and microelectronics. Extensive and growing needs from this industry have raised the significance of accurate measurements of the amount of substances and material properties. For the first time, this paper presents information on how chemical metrology is being applied to meet a variety of needs in the aspects of quality control of electronics products and environmental regulations closely associated with electronics industry. For a better understanding of the roles of the chemical metrology within electronics industry, the recent research activities and results in chemical metrology are presented using typical examples in Korea where electronic industry is leading a national economy. Particular attention is paid to the applications of chemical metrology for advancing emerging electronics technology developments. Such examples are a novel technique for the accurate quantification of gas composition at nano-liter levels within a MEMS package, the surface chemical analysis of a semiconductor device. Typical metrological tools are also presented for the development of certified reference materials for fluorinated greenhouse gases and proficiency testing schemes for heavy metals and chlorinated toxic gas in order to cope properly with environmental issues within electronics industry. In addition, a recent technique is presented for the accurate measurement of the destruction and removal efficiency of a typical greenhouse gas scrubber.

Contents

1. Introduction

The advance of a country entails changes and advances in its industrial structure and subsequently those in the national

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measurement standards. In Korea, industrial sectors such as steel, automotive, petroleum chemistry, and construction led the national economy until the 1990s. At this period, Korea Research Institute of Standards and Science (KRISS), the national metrology institute of Korea, has met such needs by providing chemical metrological standards such as a suite of certified reference materials (CRMs) to a wide range of industrial demands and national agenda. Electronics technology has rapidly transformed and led the entire industry of Korea since 1990. In such industrial environments, KRISS are playing a pivotal role in research and development of chemical standards relevant to electronics industry of Korea. The electronics industry deals primarily with semiconductor materials, electronic displays (e.g., liquid crystal display; plasma display panel), nanomaterials, etc. Extensive roles of chemical metrology in electronics industry involve high yields and quality controls of products, environmentally friendly management, and regulatory sectors closely relating to the international trade of industrial products.

In order to pursue the demands for higher product yields and better quality control, a variety of CRMs are required, particularly for thickness determinations, surface chemical analyses, and gas analyses. A number of CRMs have also been essential to environmental metrology due to the restriction of the use of hazardous substances in electrical and electronic equipment (RoHS). Examples include CRMs for a number of gases such as NO_x, SO_2, HCl, HF, and volatile organic compounds and those for waste environmental measurement. International and domestic regulatory sectors pose strict regulations on the production of emerging greenhouse gases generated from electronics industry such as perfluorocompounds (PFCs) that include CF_4, NF_3, and SF_6. Any measurement results would be considered appropriate, only when verified procedures such as International Organization for Standardization (ISO), American Standard Testing Methods (ASTM), CRMs, and proficiency testing (PT) schemes for laboratory personnel are sufficiently met.

In the current literature, it is very difficult to find the organized information on why and how much chemical metrology is critical for sustaining and advancing electronics industry. For the first time, we present a comprehensive understanding of how chemical metrology is playing important roles in supporting electronics industry by presenting recent case studies in regard to quality controls and associated environmental issues. For a better grasp of the entire picture, typical examples are demonstrated with an emphasis on the development and dissemination of measurement standards such as certified reference materials and on the conducting proficiency testing schemes for a variety of chemical measurement activities as common practices in electronics manufacturing industry in regard to heavy metals, greenhouse gas, and toxic acid gas. Other metrological applications were also briefly discussed, such as the precise measurement of gas composition inside of the internal nano-liter cavity of a micro-electro-mechanical system (MEMS) package, the surface chemical analysis of a semiconductor material, and the accurate determination of destruction and removal efficiency of a typical greenhouse gas scrubber.

2. Chemical metrology for quality control and technology innovation

2.1. Development of measurement techniques and various certified reference materials for surface chemical analysis

Surface composition and its in-depth distribution of constituent materials are important issues in the advanced industries. Recent international technology roadmap for semiconductor showed that the reliable depth profiling analysis of doping elements in the shallow junction region and the thickness measurement of ultra-thin gate oxides are required for the next generation of semiconductor devices. X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES) and secondary ion mass spectrometry (SIMS) are the main techniques for surface chemical analysis. SIMS is useful for the quantification and depth profiling analysis of minor impurities in the fields of semiconductor and new materials because of its high sensitivity and detection capability of all elements including hydrogen. XPS and AES are mainly used for the quantification and depth analysis of major components. In addition, diverse focused ion beam (FIB) based techniques such as FIB microscope and dual platform of FIB with sequential or simultaneous scanning electron microscope (SEM) imaging has been widely used, most significantly in the field of inspection of integrated circuits and electronic devices manufactured by the semiconductor industry in order to derive in depth information [1–3].

International Organization for Standards (ISO) and Versailles Project on Advanced Materials and Standards–Surface Chemical Analysis (VAMAS–SCA) have started to systematically research on international standardization of surface chemical analysis [4]. In addition, international comparisons of surface analysis by National Metrology Institutes (NMIs) have been launched by the Surface Analysis Working Group (SAWG) of the Consultative Committee for Amount of Substance (CCQM) since 2004. The thickness determination of ultra-thin SiO_2 thin films on Si (100) and Si (111) substrates was the first key comparison (KC) through CCQM-K32 by SAWG [5,6]. XPS was found to be the most powerful technique for the determination of the thickness of a gate oxide in the thickness range of nanometer and sub-nanometer [7–9]. An international key comparison on measurement of composition of a thin Fe–Ni alloy film (CCQM-K67) was proposed and recently completed by KRISS, the coordinating laboratory [10–12].

KRISS developed an ion beam sputter deposition system to grow various thin film CRMs [13]. The target materials are sputtered by Ar ions and deposited on Si wafers using a rotating substrate holder. Many kinds of binary alloy films and multilayer films can be grown by this system. The surface composition and chemical state of the films grown in the deposition system can be analyzed by in-situ XPS analysis. Three kinds of thin film CRMs have been developed by KRISS for the standardization of surface chemical analysis as shown in Table 1.

The multilayer CRMs are usually used to optimize the analysis conditions and to evaluate the depth resolution. ISO 14606 descri-

Table 1
The KRISS reference materials of thin film for surface chemical analysis.

Use	KRISS CRM identifier [44]	Surface structure
Multilayer thin films for depth profiling	103-04-001	Ta_2O_5/SiO_2 multilayer thin film
	103-04-002	Ta_2O_5/Ta multilayer thin film
	103-04-003	Si/GaAs doped Si multiple delta-layer
	103-04-004	Si/B-doped Si multiple delta-layer
	103-04-007	Si/Ge multiple delta-layer
Quantitative analysis by XPS and AES	103-04-011	Pt–Co alloy thin film
	103-04-012	Fe–Ni alloy thin film
	103-04-013	W–Si alloy thin film
Quantitative analysis of B in Si by SIMS	103-04-031	B doped Si thin film

Notes: XPS = X-ray photoelectron spectroscopy; AES = Auger electron spectroscopy; SIMS = secondary ion mass spectrometry.