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Spectroscopic ellipsometry: a historical overview

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Abstract

The historical development of spectroscopic ellipsometry (SE) from the very early stages to the present will be briefly reviewed. It is shown that SE is a truly powerful technique of great interest and use to physicists, chemists, electrochemists, electrical and chemical engineers, etc., as will be evident from the following few of the many reasons. (a) Firstly, the full spectra of the ellipsometric parameters Δ and Ψ as a function of wavelength from UV to IR can now be determined with a high degree of precision and accuracy in a few seconds. (b) Such data can also be processed to provide (i) the most accurate values to date of the dielectric functions (i.e. the real and the imaginary parts of the optical dielectric constant as a function of wavelength) of semiconductors, metals and even wide band gap materials available only as thin films; (ii) depth-profiles of interfaces, thin films and multilayer structures with almost atomic resolution; (iii) the composition for any layers (bulk, interface, or surface) that are composites or alloys; (iv) the microroughness of the surface layer; and (v) the true near-surface temperature of the samples in their preparation chamber in the case of semiconductors. Furthermore, it will be shown that the above results obtained by SE are reliable and trustworthy, by the excellent corroboration with the results of XTEM, RBS and AFM studies on the same multilayer structures. In real-time spectroscopic ellipsometry (RTSE), which has just been developed and perfected, most of the above capabilities of SE can be achieved again through analysis of data collected in a matter of a few seconds, and hence RTSE is now ready for use in real-time monitoring and control during the growth of multilayer structures, thin films, etc. Thus the full potentialities and capabilities of this non-destructive, non-perturbing and non-invasive technique are yet to be realized. © 1998 Elsevier Science S.A.

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1. Introduction

I think the best way to start this historical review of spectroscopic ellipsometry (SE) is to start with the very first fundamental ellipsometric study reported in the literature, even though it was not called 'ellipsometry' at that time. The credit goes to Paul Drude (Fig. 1) who not only derived [1] the equations of ellipsometry, which are in use even today for the interpretation of the results, but also carried out the first experimental studies [2–5] on both absorbing and transparent solids with and without any overlayers. At this point I should acknowledge the contributions of other earlier workers including Malus, Brewster, Fresnel and Lord Rayleigh who had also made pioneering studies in areas of importance to the development of ellipsometry but on transparent materials only. Here a few brief remarks about Drude are appropriate.

Paul Drude, born in 1863, wanted to be a mathematician and hence started his studies in mathematics in Gottingen. He then moved to Freiburg and Berlin before returning to Gottingen in 1886, when he met Prof. W. Voigt who became his mentor and guide. Under Prof. Voigt he became interested in theoretical physics and started his dissertation work on the 'Reflection and Refraction of Light at the Boundaries of Absorbing Crystals'. The very first crystal he studied to check his theory was antimony sulfide Sb_2S_3, an orthorhombic (optically biaxial) crystal. The experimental difficulties were great and yet he immediately

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