FOUR-TERMINAL NONDESTRUCTIVE ELECTRICAL AND GALVANOMAGNETIC MEASUREMENTS

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I. INTRODUCTION

One of the well-established procedures used for a quantitative evaluation of the electrical properties of semiconductors is the measurement of their resistivity. Modern technological processes, particularly those concerned with manufacturing of semiconductor devices and integrated circuits require that such measurements be made not only of the spatial average of macroscopic specimens but also of localized microscopic fluctuations in their resistivity. Such fluctuations may be present in virgin semiconducting wafers cut from a single crystal boule; they may be due to a radial and axial microsegregation of impurities during growth or to defects generated by sawing, slicing or other forms of plastic deformation to which a wafer may be subjected during preliminary handling before it is accepted for further processing. Changes in resistivity and its spatial distribution may also occur in a wafer during any one or more of the various stages of device or integrated circuit fabrication procedures. These process-induced changes can serve as diagnostic tools for monitoring and quality control of a fabrication process. Complementary Hall effect measurement, used in conjunction with resistivity measurements yield more complete and better data. They can provide the spatial average and the fluctuations in free carrier concentration and mobility as a function of parametric variations of a technological process. The object of these lectures is to present a description of those methods and techniques used
for nondestructive quantitative four-electrode characterization of the resistivity, Hall coefficient, carrier concentration and mobility of electronic materials.

II. THE COLLINEAR FOUR-PROBE ARRAY

A collinear four-probe (CFP) array probe can be used to measure the resistivity of specimens having a wide variety of shapes including those with irregular boundaries as well as the resistivity of smaller regions included in a matrix with different electrical properties. Collinear four-probe measurements are used extensively in the silicon device and integrated circuit technology for the evaluation of Si wafers, epitaxial layers, ion implanted regions and impurity diffusion processes. Figure 1 shows schematically a representation of a CFP array. It consists of four pointed equispaced probes in contact with a plane surface of a uniform isotropic material to be measured. The probes are considered to be far from any of the other boundaries of the specimen so that the latter may represent an essentially semi-infinite volume of uniform resistivity. Further constraints applicable are:

Fig. 1. Collinear four-probe array on a semi-infinite sheet of thickness, δ; outer probes 1 and 4 are the current input and output probes, inner probes 2 and 3 measure the potential difference, V, between them.