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Scanning Acoustic Microscopy for Study of Interfaces in Solid-State Devices*

C.S. Tsai, J.K. Wang, and C.C. Lee
Center for the Joining of Materials
and
Department of Electrical Engineering
Carnegie-Mellon University
Pittsburgh, Pa. 15213, U.S.A.

Acoustic Microscopy is based on material parameters such as the elastic modulus, mass density, and acoustic absorption rather than the index of refraction and absorption coefficient in optical microscopy. Consequently, acoustic microscopy is not limited to transparant materials nor are destructive sample preparations necessary. The instrument that has evolved is called the Acoustic Microscope. Two types of acoustic microscopes were developed recently. This paper concerns the one which is called the scanning acoustic microscope (SAM).(1) A spatial resolution comparable to that of the optical microscope has been demonstrated most recently with a reflection-type SAM.(2)

A transmission-type SAM(1,3) consists essentially of an acoustic signal generator, two acoustic lenses, liquid cell, precision sample holder, three-dimensional mechanical scanning system, acoustic detector, signal processing electronics, and a storage CRT. The acoustic signal is generated by a piezoelectric transducer which is bonded to one end face of a sapphire rod. An acoustic lens at the other end face of this rod allows the acoustic energy to be focused to a diffraction-limited spot. The focused acoustic beam then illuminates the sample suspended in the liquid, e.g. water. The acoustic beam is thus reflected, refracted, scattered and attenuated at regions in the sample where variations in the elastic parameters occur. The transmitted acoustic signal is collected by an identical acoustic lens and reconverted to an electrical signal by a second piezoelectric transducer. The electrical signal is then processed using a superheterodyne receiver and displayed on the CRT in the form of an intensity-modulated image. By scanning the sample both laterally (in raster scan) and in depth, focused acoustic <u>amplitude</u> images corresponding to all points in the sample can be displayed on the CRT. In addition, both amplitude and <u>phase</u> of the transmitted acoustic signal at all points in the sample can be measured directly. Phase information is equally important because local variation in the acoustic phase is a measure of the variation in elastic modulus and/or mass density.

We had earlier employed a transmission-type SAM operating at 150 MHz to image and detect the irregularities in simple materials and specially made material joints between dissimilar materials of large thickness.(3,4) More recently, we have also employed the same microscope to examine the interfacial regions of thick production-line microelectronic components.(5) Flaws, voids, and defects in thse specimens have been detected. Some characterization of these defects has also been obtained.(6) For example, the acoustic micrograph obtained with a production-line multilayer thin-film resistor clearly depicts the boundaries and the defects in the multilayer structure which consists of alumina substrate (375 μm) - NiCr (~ 1 μm) - SiO (~ 1 μm) - coating (50 μm). It is to be noted that no other nondestructive method is available to image such boundaries and defects.

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Presently, research on further application of this instrument to the nondestructive study of interfaces in passive and active solid-state components/devices is being carried out. Examples of the former are thick- and thin-film electronic circuits, multilayer chip capacitors, metallic thin-film couples, and thin-film contacts and bonding pads. Examples of the latter are high power silicon transistor headers, beam lead devices, solar cells, and laser diodes. The electrical, thermal, and mechanical characteristics of many solid state components and devices are greatly influenced by the elastic defects which occur in their interfacial regions. It is thus desirable to detect, identify, and characterize these defects using this acoustic instrument. Significant new results have been obtained most recently. For example, we have developed a simple and reliable characterization method to distinguish between voids and inclusions.

In this paper, the up-to-date advances we have made on the research described above will be reported. First, the basic principles, unique features and capabilities of the scanning acoustic microscope,and its most recent advance with regard to spatial resolution are described. Applications to nondestructive visualization and characterization of the interfacial regions of the various types of multilayer solid state components and devices referred to above will then be discussed in detail.

References

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