Scanning Acoustical Microscopy
Part II: Applications

Jacqueline Gallet, Ph.D., University of California, Irvine

Scanning acoustical microscopy has found a very comfortable niche in the area of non-destructive evaluation, testing and imaging. But the field need not be limited by such a narrow applications area.

In this article, a general review of current and possible applications will be conducted including archaeological conservation and evaluation. Part III of this series will deal exclusively with biomedical applications.

Since acoustical waves can penetrate a specimen, optically opaque materials can be visualized and more fully examined. Depending on the resolution required, a compromise needs to be achieved before a specimen can be imaged. Recall from Part I of this series, the higher the frequency, the better the resolution, but the depth of penetration is less. In many applications, it is not always necessary to achieve a high degree of resolution, it is more interesting to locate and identify internal structures. Acoustical microscopy is meant to be a complementary form of observation not necessarily a stand-alone modality.

Every application area requires that an interface fluid be present between the transducer-lens system and the specimen under observation. In most cases, deionized water is adequate. The change in impedance between the water and the specimen will be sufficient to generate acoustic reflections; therefore, visualization is feasible. Other fluids which can be utilized are mineral oils and alcohols. For each fluid used, gating information needs to be manually determined and set. This is dependent on the speed of sound through the media. In oil-based media, the speed of sound is much slower than in water.

Not only visual information is important to obtain. Because of the underlying physical principles which exist between acoustical waves and specimens, viable quantitative information can also be extracted.

Let us examine the type of information which can be deduced from the UH3 Scanning Acoustic Microscope.

There are basically 5 parameters of interest in acoustical microscopy. These are velocity, impedance, attenuation, elasticity and V(z) profiles where the Rayleigh velocities and a relative attenuation as a function of focal depth can be calculated. Each parameter is a unique signature of the specimen insonified. If one can calculate one of these five parameters, this would uniquely characterize the specimen.

As an example of an image application, consider coins and metal based artifacts from an archaeological find. In this case, one would first want to image non-destructively through layers of caked silt. In the lowest frequency pulse-mode, the artifact can be gently immersed in a water-bath. The field of view can be set to its maximum (4x3 cm), and the artifact can be scanned in sections. One can also image at incremental depths to reconstruct a full three dimensional image of the object. Needless to say that only objects which can tolerate water immersion can be visualized in this manner.

It is also of interest, that "shadows" of imprints can be observed in coins. This is quite significant in determining exact words or figures on coins even though to the human eye very little can be differentiated.

Consider Figures 1 and 2 where the non-face side of each penny was milled and lapped to the extent that visually it appeared as a shiny surface. A 30 MHz transducer was utilized to allow penetration of the acoustical waves. The gating was such that reflections from both the top and bottom sides of the penny were included. In Figure 1, a 1959 penny, no reflections from the backside are noticeable. On the other hand, in Figure 2, the 1990 penny, there is a discernible shadow of its backside imprint - even though visually there is nothing to see with the naked eye. The metal content of these two issues of pennies is quite different, leading to the conclusion that the imprint of the non-face side of the older coin had been pressed into its crystalline structure. This type of investigation could be used to its full advantage when determining appropriate metals behaving acoustically in a similar manner.

The more traditional visualizations are in the observations of integrated chips and wafers. Figure 3 is a demonstration of an IC wafer taken a 1 GHz. Defects in bonds can be easily detected at this high frequency. Another type of visual information obtained with the UH3 Scanning Acoustic Microscope is the observation of fiber composite materials. Since composite materials consist of fibers of differing elastic properties, acoustical waves will interact in a very distinct manner. This will yield an image of the individual fibers and their orientation.

Particle composite materials will also yield images delineating the number of particles in a certain volume. The acoustical image in this instance is possible because of the change in physical density of the material. The particles are forced into the composite material causing stress associated with the integration of these foreign particles. Thin films, metals, and ceramics can also be visualized for delaminations, surface and internal defects, location of forcing substances, and solidity of weld joints.

Other visualization methodologies consistent with this specific microscope are 3Z imaging, where the signal intensity is displayed as an amplitude. Small changes in gray scale intensity are more readily visible in this method. At this point in the display, one can also apply pseudo-color to further enhance small variations.

The capability of merging three images taken at distinct incremental depths but of the same field of view is possible as well. Each image displayed is in either red, green or blue. The resultant image can contain up to 16 million hues to enhance minute variations in density or elasticity. Thickness measurements can also be calculated and displayed digitally be monitoring the reflections from the top and bottom surface of the specimen.

These are only a few of the many visual and quantitative features available to the Olympus UH3 Scanning Acoustic Microscope. Part III of this series of articles will concentrate on the applications of the microscope to the biomedical field. This is an exciting new applications area with opportunities for innovative industry-university cooperative projects. ■

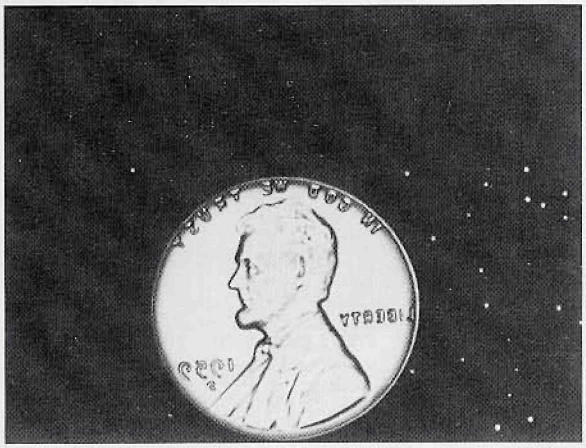

Figure 1: Acoustical image taken at 30 MHz of a 1959 penny with backside shaved. White dots in background represent air bubbles. Reflections from top and bottom surfaces were gated in to produce this image.

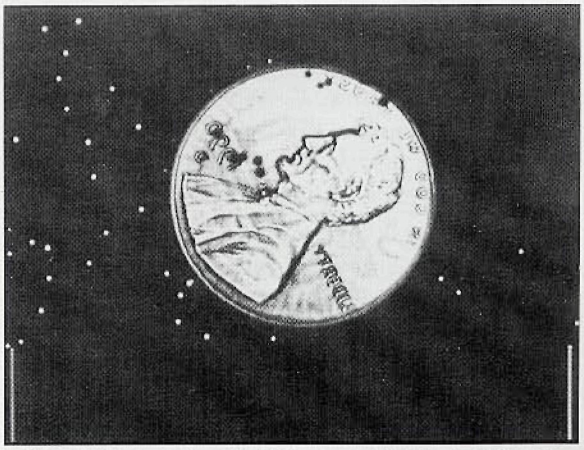

Figure 2: Acoustical image taken of a 1990 penny at 30 MHz, backside of penny was milled. White dots in background are air bubbles. Black dots on penny are also air bubbles which have undergone a change in phase (as compared to background signal). Notice that the shadow of the backside is acoustically visible but not obtically visible.

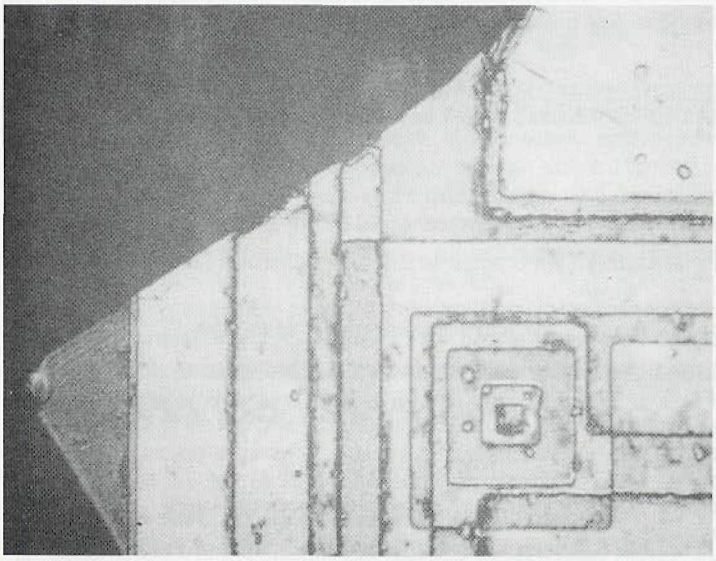

Figure 3: Acoustical image of silicon wafer chip taken at 1 GHz.

SOIL TECHNOLOGY, A COMING FIELD AND A NEW MICROSCOPY TO SUPPORT IT

Sterling P. Newberry, Consultant

A quiet report from an international work shop, this fall in London on World Ecology, points out how primitive our knowledge of basic soil science really is (1). It also records the determination of the participants to bring out the need to study soil in relation to maintaining biodiversity because of man's rapid destruction of global habitat and the inability for soil to recover without it's natural canopy of plant and animal life. It is further pointed out that we have to quickly learn how to reclaim soil, perhaps by artificial means, after insult. The programs they envision will create exciting professional opportunities both for career change and for students over a broad spectrum from basic research to applied engineering. The land fill crises has further underscored the need to find ways to return sewage sludge and other organic waste to useful crop production.

X-Ray Microscopy in the ultra soft region has recently been shown to be an ideal tool for studying the complex structure and chemistry of soils (2). This paper by Thieme et. al. at our New Orleans meeting, employed x-ray microscopy from a Synchrotron light source. By fine tuning of the wavelength employed, they were able to demonstrate spectroscopically differentiated images of soil components including organic materials in colloidal suspension. They also demonstrated direct measurement of clay mineral pore geometry and volume for the first time. One of the surprising results was that the washing of sludge with detergents binds heavy metals into the soil rather than removing them as expected. Then the vegetables and/or stock feed later extracted the mercury, cadmium etc. for delivery to our tables via our food chain. As the authors point out, the combined resolution and penetration of the soft x- rays cannot be matched by either the optical or electron microscopes in the native, aqueous, living state so necessary for studying soil systems. We look forward to seeing a full publication of this work, since they reported much more than the material given in the extended abstract. ■

1. Peter Aldhous, Ecologists Draft Plan to Dig in the Dirt, Science 265:1521, September 9, (1994).
2. J. Thieme, J. Niemeyer, P. Guttmann, Colloidal Systems in Soils, MSA Proceedings (1994), p. 64-65.