

yet easy to comprehend. For example, PIN1 protein expression is low in *avp1* mutants, yet plants overexpressing AVP1 do not really show the opposite phenotype. Similarly, it is difficult to explain why auxin transport is enhanced in the root tip but reduced at the root-shoot junction upon increased AVP1 expression. Despite these discrepancies, the authors' findings clearly support the notion that AVP1 affects auxin transport. Future studies may help to explain differences at the level of specific cell or tissue types.

In light of its unexpected role in auxin transport regulation, Li *et al.* (6) also address a potential function of AVP1 in cell wall acidification. Intriguingly, absence of AVP1 increases the cell wall pH, whereas overexpression of AVP1 lowers pH. Control of cell wall pH has been attributed to the plasma membrane proton pump, P-ATPase. Indeed, *avp1* mutants display reduced P-ATPase activity, whereas plants overexpressing AVP1 have increased P-ATPase activity and density at the plasma membrane. Thus, Li *et al.* uncover an unexpected role for AVP1 in the regulation of cell wall acidification by modulating P-ATPase levels—"acid growth" revisited?

Li *et al.* demonstrate AVP1 action on polar auxin transport and P-ATPase-mediated cell wall acidification. In addition, their study raises exciting questions. The authors report elongation defects in root cells versus reduced leaf cell numbers in *avp1* mutants (6). Does this indicate that AVP1-regulated cell wall acidification mediates cell expansion according to the acid growth theory in roots but not in leaves? Or does AVP1-mediated regulation of cell wall pH mostly feed back on auxin transport, taking into account the chemiosmotic model? Whichever of the two processes may be primarily affected by AVP1, it will be interesting to see how cell wall acidification and auxin transport are connected. The authors hypothesize that AVP1 somehow regulates transport of both P-ATPase and PIN1 to the plasma membrane by acidifying an unknown subcellular compartment along a common transport route. This idea can now be tested by extending the loss- and gain-of-function approaches (6) to detailed cell biological analyses. These should clarify to what extent AVP1, PIN1, and P-ATPase take common routes and whether AVP1 regulates vesicle transport. A hint of where this V-PPase could act comes

from studies on cauliflower where a V-PPase pump resides at the trans-Golgi network, in multivesicular bodies, the vacuole, and at the plasma membrane (10). Thus, there are several options as to where AVP1, PIN1, and P-ATPase could meet along the secretory or endocytic pathway. Undoubtedly, the work of Li *et al.* (6) opens new views on the regulation of auxin transport and proton pump action during plant development. Further detailed understanding of AVP1 subcellular function will help to merge or distinguish different concepts of auxin transport and action.

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## APPLIED PHYSICS

# Subsurface Imaging with Scanning Ultrasound Holography

Alain C. Diebold

Characterization of subsurface structure is critical to almost every area of science and engineering (1). In biology, for example, imaging the structure of cells has always been a fundamental means of understanding the relationship between structure and function. Moreover, every innovative microscopy technique seems to highlight new or difficult-to-observe features in biological systems. But some problems, such as finding life-threatening arterial blockages, require much better spatial resolution (1).

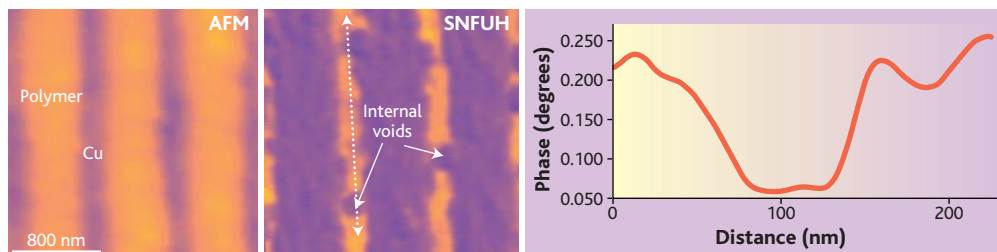
Some key microscopic imaging methods rely on sound waves rather than light. Perhaps the most prevalent application of acoustic microscopes is for imaging subsurface features in packaged electronic parts. Subsurface voids can be the root cause of coating delamination or can result in the fracture of a critical structure

under stress. As Shekhawat and Dravid report on page 89 of this issue, a novel form of acoustic holography has now extended the spatial resolution of this technique, thus enabling the imaging of subsurface features in a wide range of applications (2).

A conventional scanning acoustic microscope focuses acoustic waves under the surface of a sample by means of a transducer (often made from sapphire) and scans the sample under the transducer. The sample is immersed in water. The spatial resolution

is given by an equation similar to the Rayleigh criterion for a light microscope, namely  $\omega = 0.51\lambda_0/NA$ , where  $\lambda_0 = v_0/f$ ,  $v_0$  is the velocity of sound in the fluid,  $f$  is the frequency of the acoustic wave, and  $NA$  is the numerical aperture. For typical acoustic microscopes, the spatial resolution is close to 100  $\mu\text{m}$ . Recently, scanning probe microscopy has extended the spatial resolution to the nanometer scale (3).

To obtain images of integrated circuit technology, however, much greater spatial resolution will be required. The width of metal lines is quickly approaching 60 nm, and by the year 2008 memory chips will have so-called dense metal lines 60 nm wide with spaces of 60 nm between them. Previous efforts had already pushed acoustic imaging resolution well below the limits of the scanning acoustic microscope. Geer *et al.* have demonstrated that the ultrasonic



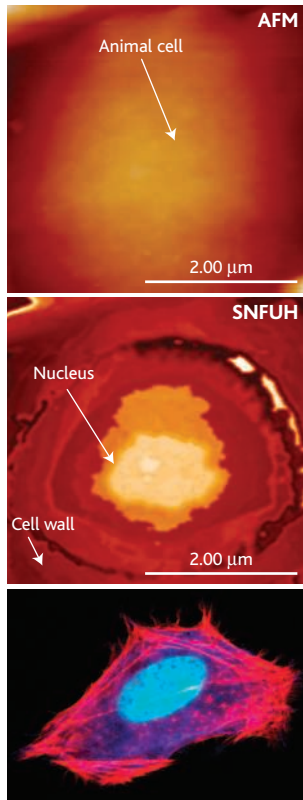
**Fine lines.** SNFUH imaging of a copper low-dielectric interconnect system. (Left) Typical AFM (topography) image shows periodic polymer and copper features. The copper lines are about 60 nm wide and the polymer one around 200 nm. (Middle) Phase image of SNFUH that clearly reveals the surface elastic contrast and subsurface voiding in the copper lines. (Right) Line profile across the voids.

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force microscope can image changes in the elastic modulus with a resolution of <10 nm (3). This group ultrasonically vibrated the sample at 2.2 MHz while scanning the surface with an atomic force microscope (AFM). The apparatus is similar to that previously reported by Dinelli *et al.* (4). The spatial resolution was good enough to observe differences in the low dielectric constant film caused by variations in the processing (3).

Now, Shekhawat and Dravid have shown how scanning near-field ultrasound holography (SNFUH) can further improve spatial resolution and depth information (2). In SNFUH, acoustic waves are launched on both the probe tip and the sample at slightly different megahertz frequencies. The interference of these two waves forms a surface acoustic standing wave. This wave is altered by subsurface features such as voids, and the change in its frequency



**Better bioimages.** (Top) Image of mouse cell taken with conventional AFM technology. (Middle) SNFUH image of the same cell. (Bottom) Micrograph of mouse fibroblast cell for comparison (nucleus is blue, actin protein in cell's skeleton is shown in red).

is monitored by the AFM cantilever. Shekhawat and Dravid operate the AFM in the contact mode for hard materials and the noncontact mode for biological materials. The next step for this approach will be to develop the modeling to determine the depth dependence of the response from buried features turning two-dimensional maps into three-dimensional tomography maps.

Shekhawat and Dravid have also applied their technology to copper damascene structures and observed voids in copper lines (see the first figure). The direct, non-destructive observation of a void in an opaque material had previously seemed to be a nearly impossible task.

But semiconductor structures are not the only application of near-field acoustic microscopy. Shekhawat and Dravid have

illustrated the imaging capability of SNFUH for biological samples. In the top panel of the second figure, a typical AFM (topography) image shows a mouse cell on a cover slip, which was treated with phosphate buffer solution. It only shows the overall outer morphology of the cell. In the middle panel of the second figure, however, the SNFUH image appears to reveal the internal substructure of the cell, including the nucleus. It is instructive to compare the SNFUH image with a typical micrograph of an animal cell (the bottom panel of the second figure). Extra structure is observed with this additional resolution. With further research and development, SNFUH should be able to provide even more information, such as the depth of buried features and further quantification of elastic properties.

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PSYCHOLOGY

# The Nature of Personality: Genes, Culture, and National Character

Richard W. Robins

I recently had the opportunity to conduct research in a remote village in the West African nation of Burkina Faso, one of the countries whose national character was studied by Terracciano *et al.* in a report on page 96 of this issue (1). While there, I was struck by the degree to which everyone seemed so different yet so familiar at the same time. Despite dramatic differences in cultural customs and practices, the Burkinabe people seemed to fall in love, hate their neighbors, and care for their children in much the same way, and for many of the same reasons, as people in other parts of the world. Indeed, there is a core to human mentality and social behavior that cuts across nations, cultures, and ethnic groups. Even such profoundly different countries as Burkina Faso and the United States do not

differ substantially in the average personality tendencies of their people, as Terracciano and colleagues have shown (1, 2).

Against this backdrop of human universals, it is quite clear that individual variability exists: Some Burkinabe (or Americans) are shy and others sociable, some friendly and others disagreeable, and some driven to attain high status in their community while others lack the same drive. Of the vast array of human personality traits, the majority can be subsumed within five broad domains: extraversion-introversion, antagonism-agreeableness, conscientiousness, neuroticism, and openness to experience. Collectively, these five dimensions predict most of the outcomes that truly matter in life—health and mortality, academic success, job performance, the capacity to have a successful and lasting romantic relationship, and a wide range of personal and societal problems, including drug abuse and criminality (3, 4). Moreover, personality traits predict such outcomes with

as much precision as many biomedical measures predict diseases, including the prediction of heart disease by electrocardiogram stress tests, pregnancy outcomes by ultrasound exams, and breast cancer by screening mammograms (5).

What accounts for individual variability on the five primary dimensions of personality? Tensions exist in the scientific literature between explaining this variability in terms of basic physiological and genetic processes, and in terms of situational, social, and cultural contingencies that vary both within and across sociocultural groups. An eminent psychologist, John Watson, once famously claimed, “Give me a dozen healthy infants . . . and my own specified world to bring them up and I’ll guarantee to take any one at random and train him to become any type of specialist I might select—doctor, lawyer, merchant-chief, and yes, even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors” (6). We now know that Watson was wrong. Genetic factors provide constraints on the way a child develops, and they account for about half of the variability in personality (in typical populations and environments). Identical twins separated at birth tend to have remarkably similar personalities, despite vastly different upbringings (7). In short, people are not blank slates upon which culture-

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