Analytically Speaking

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Characterization of Deposits, Coatings & Electroforms

Mechanical Properties Measurement

Mechanical properties are of the greatest relevance to deposits on printed-circuit boards and to electroforms. A number of other instances occur where the mechanical properties of deposits are of importance. Hardness is most often measured, even though it is not a fundamental material property, because it is the easiest to determine. The properties obtained from a tensile test (*i.e.*, Young's modulus, the yield and tensile strengths and the percent elongation) are easier to interpret. The fatigue properties and those resulting from thermal cycling are also relevant in some cases. The test methods will be discussed together with the calculation of the properties from the test data.

Hardness Testing

Hardness testing of deposits consists of pushing an indenter into the material. A load is applied to the indenter for a specified time. After removing the load and permitting elastic recovery, the hardness is calculated from the dimensions of the indentation. In most cases, the indentation is made on the cross section of the deposit that had been prepared in the same way as that for examination in an optical microscope. This method was described earlier. The reason for usually not measuring the hardness on the deposit surfaces is the so-called anvil effect, that is, the substrate under the material being tested influences the hardness value unless the depth of the indention is less than about one-tenth of the thickness. To test the hardness of surfaces, special equipment is needed.

The two most widely used hardness tests for deposits are the Vickers and Tukon tests. The Vickers indenter is a diamond having a pyramidal shape with a square base. The two diagonals of the square impression on the surface where the indentation was made are measured. The so-called diamond-pyramid hardness number (DPH) is calculated by:

$$DPH = 1.854\ L/D^2 \qquad (1)$$

where L is the load in kilograms and D is the average of the lengths in millimeters of the two diagonals. In most instruments, the load is applied through an oil dashpot. As soon as the dashpot reaches the end of its travel, the load is removed. The duration of the load application can be made to vary from 10 to 30 sec and is accordingly determined. The value of the DPH depends on the load, which always must be specified. A number of indentations should be made and the DPH values averaged.

The Tukon test uses the so-called Knoop indenter, also a diamond having a pyramidal shape. The shape of the indentation on the surface is a rhombus, that is, one diagonal is longer than the other. The Knoop hardness number (KHN) can be calculated by:

$$KHN = L/0.07028D^2 \qquad (2)$$

where L is again the applied load in kilograms and D is the length of the longer diagonal in millimeters. Again, a number of indentations should be made and the results averaged. The advantage of the Knoop indenter over the Vickers for deposits is that the length of the longer diagonal can be parallel to the thickness. The thickness determines the load that can be applied. The diagonal of the Vickers indenter and the smaller of the Knoop diagonals should be less than half the thickness. The Knoop indenter deforms a larger volume of material for a given load, so that its larger diagonal can be measured more accurately.

To measure the hardness on the surface of relatively thick deposits and the cross section of thin ones, the superficial hardness tester must be used. It employs lighter loads than a regular tester and makes smaller indentations. A nanohardness tester can be used to measure the hardness on the surface of thin deposits. It uses a smaller indenter and very light loads. The size of the indentation is so small that it must be measured by a scanning electron microscope.

Fatigue Testing

Fatigue occurs when the stress varies in a cyclical way. The fracture stress in fatigue is mostly much smaller than that measured in a tensile test. Fatigue tests are generally conducted by varying stresses from compressive values to equal tensile ones and noting the number of reversals that result in fracture. Regular fatigue testing of deposits can only be conducted while they are attached to more massive substrates. It is impossible to apply compressive stresses to a thin foil because it buckles; therefore, fatigue test of thin foils must be conducted by varying the stress from zero to tensile values.

The most common cases of fatigue involving electrodeposits is in thermally cycled electronic components and in aircraft parts. Thermal cycling results in fatigue because the varying stresses resulting from the different coefficients of expansion of the deposit and the substrate. Thermal-cycling tests are most often conducted to test for this type of fatigue. A means of fatigue testing of thin foils was described by Hong and Weil,[1] using the machine discussed in Reference 2. **P&SF**

References

1. S. Hong and R. Weil, *Thin Solid Films*, **283**, 175 (1996).
2. I. Kim and R. Weil, *Testing of Metallic and Inorganic Coatings*, ASTM STP 947, H.D. Harding and G.A. DiBari, Eds., ASTM, Philadelphia, PA, 1987; pp. 11-18.