Reprinted from the *Indian Journal of Pure & Applied Physics*, 1966, Vol. 4, No. 9, pp. 365-366

A Circuit for Monitoring the Thickness of Films during Vacuum Deposition

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Manuscript received 9 *March* 1966

A practical, field tested, transistorized circuit for monitoring the thickness of vacuum deposited thin films is described. The circuit utilizes the beat frequency techniques and measures the thickness of film deposited on a crystal by the change in its resonant frequency. The method has an accuracy comparable to that of measurements made with multiple beam interferometry.

IT is usually necessary to control the thickness of films during vacuum deposition, which in actual practice means that a method should be devised so that the evaporation is stopped when the desired thickness has been reached. One method is to use the principle that the resonant frequency of a quartz crystal is changed when the mass of one of the electrodes is changed by condensing metal vapour on it. This concept is not new, but to the author's knowledge, no practically operating circuit has been published so far. A bread-board model of a circuit, which is very cheap and easy to build, is presented in this communication.

Circuit description — A detailed circuit diagram is presented in Fig. 1. Part (a) of Fig. 1 is mounted on a 5×3 in. metal chasis. The circuit to the left of the line SS′ is shielded from the right of SS′ by a thick metal plate with two or three tiny holes to run the connecting wires. XTL 1 is a socket for the standard crystal whose frequency of oscillation is exactly known. To test the output of this standard oscillator, a test jack A is provided. One end of a coaxial cable can be connected to this jack and the other end to an oscilloscope, to meausre the exact frequency of this standard oscillator.

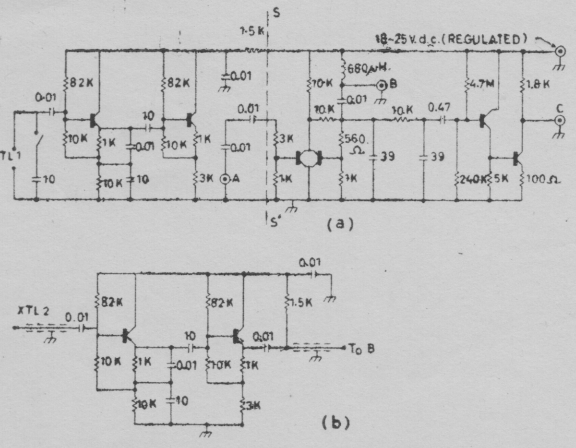

Fig. 1 — Circuit for measuring the thickness of vacuum deposited thin films [(a) Standard oscillator section; and (b) auxiliary oscillator section containing the test crystal. Values of the condensers are in μF.]

Part (b) of the figure is mounted on a separate $1\frac{1}{2} \times 1\frac{1}{2}$ in. chasis and is installed inside a vacuum chamber. XTL 2 is the socket for the crystal whose frequency is unknown. Both sockets XTL 1 and XTL 2 are of the same kind, but XTL 2 has an additional provision for the connections of the crystal elements (electrodes) when taken out of the capsule. Thus, during the experimental stage, the standard socket XTL 2 is used and during the evaporation state, the electrodes of the crystal are removed from the capsule and the alternate facility provided is utilized. The electrodes inside the vacuum chamber should be located in a position such that the rate at which the evaporated metal is deposited on this electrode is exactly the same as the rate at which the metal is getting deposited on the substrate in question. As evaporation progresses, the mass of this electrode increases which in turn changes the frequency of the 'test' oscillator to which it is connected. The output of this test oscillator is taken out of the vacuum chamber by means of a coaxial cable and connected to the jack B.

A beat frequency output appears at C as long as the frequencies of the standard and test oscillators differ. Because the exact frequency of the standard oscillator is known, the frequency of the test oscillator can be easily computed. As the vacuum deposition progresses, the beat frequency changes and the thickness of the deposited film can be monitored continuously.

Two quartz crystals (of Texas Instruments Inc.) with resonant frequencies at about 5000 ± 10 kc/s. are used in the apparatus designed by the author. All transistors used are RCA's 2N384's or 2N1396's. Mica or ceramic capacitors can be used. All resistors are 0·1 W., 5 per cent tolerance carbon resistors. A regulated power supply of 18-25 V. d.c. is sufficient to drive the circuit. A high precision frequency meter is used to measure the beat frequencies.

Calibration — It is easy to get beat frequencies in the range of 4-5 kc/s., facilitating measurements up to 1000 A. thick films. This system has to be calibrated against a direct film thickness measurement, and can be made as accurate as measurements made with multiple beam interferometry. Whenever the material to be evaporated is changed, a new calibration is required.

This circuit was built, tested and used for depositing gold films on glass slides. The electrodes of the crystal used inside the vacuum chamber have to be cleaned after each experiment, and perhaps have to be replaced after a couple of experiments. If the circuit is used in conjunction with the measurement of the thickness of magnetic films, it is advisable to use quartz crystals with evaporated gold electrodes. Then the magnetic material can be dissolved in ferric chloride solution and the gold electrodes can be used again and again.