The Microwave Magnetron Tube Structure and OperationThe Magnetron Tube

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The Microwave Magnetron Tube
Structure and Operation

The heart of every microwave oven is the high voltage system . Its purpose is to generate microwave energy. The high−voltage components accomplish this by stepping up AC line voltage to high voltage, which is then changed to an even higher DC voltage. This DC power is then converted to the RF energy that cooks the food.

Basic Magnetron Structure
The nucleus of the high−voltage system is the magnetron tube . The magnetron is a diode−type electron tube which is used to produce the required 2450 MHz of microwave energy. It is classed as a diode because it has no grid as does an ordinary electron tube. A magnetic field imposed on the space between the anode (plate) and the cathode serves as the grid. While the external configurations of different magnetrons will vary, the basic internal structures are the same. These include the anode, the filament/cathode, the antenna, and the magnets
The ANODE (or plate) is a hollow cylinder of iron from which an even number of anode vanes extend inward (see Fig. 2). The open trapezoidal shaped areas between each of the vanes are resonant cavities that serve as tuned circuits and determine the output frequency of the tube. The anode operates in such a way that alternate segments must be connected, or strapped, so that each segment is opposite in polarity to the segment on either side. In effect, the cavities are connected in parallel with regard to the output. This will become easier to understand as the description of operation is considered.

The FILAMENT (also called heater), which also serves as the cathode of the tube, is located in the center of the magnetron, and is supported by the large and rigid filament leads, which are carefully sealed into the tube and shielded.

The ANTENNA is a probe or loop that is connected to the anode and extends into one of the tuned cavities. The antenna is coupled to the waveguide , a hollow metal enclosure, into which the antenna transmits the RF energy.

The MAGNETIC FIELD is provided by strong permanent magnets, which are mounted around the magnetron so that the magnetic field is parallel with the axis of the cathode.

Basic Magnetron Operation
The theory of magnetron operation is based on the motion of electrons under the combined influence of electric and magnetic fields. For the tube to operate, electrons must flow from the cathode to the anode.
There are two fundamental laws that govern their trajectory:
The force exerted by an electric field on an electron is proportional to the strength of the field. Electrons tend to move from a point of negative potential toward a positive potential. Figure 3−A shows the uniform and direct movement of the electrons in an electric field with no magnetic field present, from the negative cathode to the positive anode.
The force exerted on an electron in a magnetic field is at right angles to both the field itself, and to the path of the electron. The direction of the force is such that the electron proceeds to the anode in a curve rather than a direct path.
Effect of the Magnetic Field
In Figure 3−B two permanent magnets are added above and below the tube structure. In Figure 3−C, assume the upper magnet is a north pole and you are viewing from that position. The lower, south pole magnet, is located underneath the page, so that the magnetic field appears to be coming right through the page. Just as electrons flowing through a conductor cause a magnetic field to build up around that conductor, so an electron moving through space tends to build up a magnetic field around itself. On one side (left) of the electron's path, this self induced magnetic field adds to the permanent magnetic field surrounding it. On the other side (right) of its path, it has the opposite effect of subtracting from the permanent magnetic field. The magnetic field on the right side is therefore weakened, and the electron's trajectory bends in that direction, resulting in a circular motion of travel to the anode.
The process begins with a low voltage being applied to the filament, which causes it to heat up (filament voltage is usually 3 to 4 VAC, depending on the make and model). Remember, in a magnetron tube, the filament is also the cathode. The temperature rise causes increased molecular activity within the cathode, to the extent that it begins to "boil off" or emit electrons. Electrons leaving the surface of a heated filament wire might be compared to molecules that leave the surface of boiling water in the form of steam. Unlike steam, though, the electrons do not evaporate. They float, or hover, just off the surface of the cathode, waiting for some momentum.

Electrons, being negative charges, are strongly repelled by other negative charges. So this floating cloud of electrons would be repelled away from a negatively charged cathode. The distance and velocity of their travel would increase with the intensity of the applied negative charge. Momentum is thus provided by a negative 4000 volts DC, which is produced by means of the high−voltage transformer and the doubler action of the high−voltage diode and capacitor . (4000 volts is an average. The actual voltage varies with make and model.) A negative 4000 volt potential on the cathode puts a corresponding positive 4000 volt potential on the anode. Needless to say, the electrons blast off from the cathode like tiny rockets. They accelerate straight toward the positive anode, or, at least they try to.

As the electrons hasten toward their objective, they encounter the powerful magnetic field of two permanent magnets . These are positioned so that their magnetic fields are applied parallel to the cathode. The effect of the magnetic fields tends to deflect the speeding electrons away from the anode, as described in page one . The illustration to the right shows the combined effect of the electric and the magnetic fields on the electrons' trajectory. Instead of traveling straight to the anode, they curve to a path at almost right angles to their previous direction, resulting in an expanding circular orbit around the cathode, which eventually reaches the anode.

The whirling cloud of electrons, influenced by the high voltage and the strong magnetic field, form a rotating pattern that resembles the spokes in a spinning wheel, as shown in Figure 4 . The interaction of this rotating space−charge wheel with the configuration of the surface of the anode produces an alternating current flow in the resonant cavities of the anode. This is explained as follows. As a "spoke" of electrons approaches an anode vane (or the segment between the two cavities), it induces a positive charge in that segment. As the electrons pass, the positive charge diminishes in the first segment while another positive charge is being induced in the next segment. Current is induced because the physical structure of the anode forms the equivalent of a series of high−Q resonant inductive−capacitive (LC) circuits. The effect of the strapping of alternate segments is to connect the LC circuits in parallel.

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