Ultra Low Susceptibility PIN Diodes for High Field

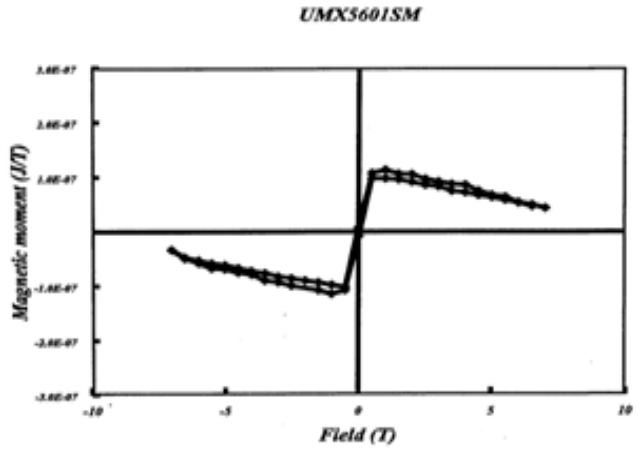
R. D. Watkins[1], W. Doherty[2], and P. Voskoboynik[3]

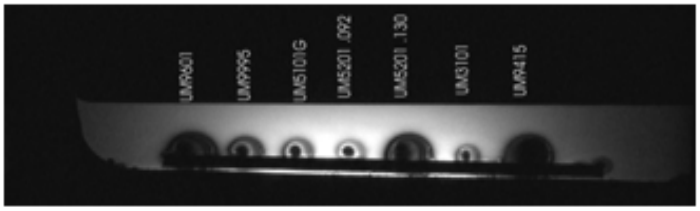
[1]Radiology, Stanford Medical School, stanford, ca, United States, [2]Engineering, MicroSemi Corp, Lowell, Mass, United States, [3]MicroSemi Corp, Lowell, Mass

ABSTRACT: Ultra Low Magnetic Moment (ULM) PIN diodes cause the smallest possible magnetic artifacts in high field MR Imaging. The UMX5601 series was designed for 3T & 4.7T MR scanners. The ULM UMX5101 series was developed for higher field 7T, 9.4T and 11.7T MR scanners. These low susceptibility PIN diodes were designed to function in high field scanners that operate at higher RF power levels & higher isotope resonant frequencies. These ULM diodes have extremely low thermal impedance and insertion loss and are RoHS compliant.

MATERIALS & METHODS: The generic PIN diode packaging provides an extremely reliable enclosure for the PIN diode silicon chip. Metallurgical bonds are used to attach the silicon chip to the pins on the cathode and anode sides of the chip. This pin-die-pin subassembly is then enclosed with a glass envelope. The silicon chips, used in this development work, are SOGO passivated [*1*]. The entire piece parts of the package must be thermally matched for expansion to prevent package failure over temperature extremes. These requirements limit the selection of package materials to a few for the basic package. Leads & other attachments to the basic package may be made of other materials. All of these conditions must be met before the magnetism of the package may be considered.

The PIN diode described here has a 0.033 cm^2 active area and an I-layer thickness of 175 µm. The goal was to design a packaged device that would have susceptibility at ≥ 3T of ±10 E-6 [±10 ppm] (SI) and would be RoHS compliant. A study was initiated to determine the susceptibility of the various metals and glasses that were available for consideration in the design of the new ultra low magnetic moment diodes. An excellent starting point is an article by J. F. Schenck [*2*]. The lowering of the magnetic moment and susceptibility was obtained by selecting negative susceptibility materials of the proper sizes that would match the positive susceptibility of the metal pins. Small amounts of Nickel are needed as a barrier layer to prevent migration. Proper bulk fractions of diamagnetic silver in the leads and end caps are used to balance to magnetic moment. The glasses used to protect the silicon die also have a negative susceptibility [*3*]. The resulting graph of magnetic moment versus magnetic field shows two different susceptibilities. Above 1T, to limit of the measurements (7T), the susceptibility is -3.1E-7 [-0.31 ppm] (SI). In the interval of 0 to 1T the susceptibility is +5.9E-6 [+5.9 ppm] (SI). This change in slope is cause by the presence of a minute quantity of a ferromagnetic material.





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RESULTS & DISCUSSION: The UMX5601 series diodes are used in higher field (B_o) scanners for active coil detune and blocking functions in surface coils that are in / near the bore's magnetic field B_o. Active switches are gated on and off in sync with the RF transmit pulse. In these applications, their diode's magnetic moment is lower than that of the adjacent materials in the switch's structure on coil's surface. This avoids additional magnetic artifacts due to the switching diodes.

Passive blocking and detune functions are performed by the UMX9989AP, an anti-parallel pair of fast switching rectifier diodes. The UMX9989AP is structured as a single assembly for ease of assembly in MR coils. These diodes are designed to turn on during the leading side lobe of the (SINC X) envelope for both 90^O flip angle pulse and the 180^O phase reversal pulse. The UMX9989AP is also used to protect surface coil receive module from RF pulses.

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