Thermosets' Cost and Reliability Advantages for Automotive Radar PCBs

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The car radar market for safety and driver assistance applications is exploding, and the critical mass makes the choice of PCB materials a key consideration amid the crucial importance of cost and reliability factors that are intrinsically linked to the automotive environment. So automakers are looking beyond PTFE and highly filled hydrocarbon resins—traditionally used in high-frequency millimeter wave applications—to lower the cost of built-in vehicle radars and ensure their reliable operation at elevated temperatures. Here, the new thermoset resins are emerging as a viable alternative for advanced automotive safety systems by offering cost and reliability advantages over thermoplastic materials.

The automotive OEMs have already introduced radars for adaptive cruise control (ACC) and collision avoidance systems in many high-end vehicles. However, the industry drive behind connected cars and autonomous or semi-autonomous vehicles is pushing automakers to consider safety and driver-assistance systems for a larger percentage of cars. There is even a debate about mandating some degree of automotive safety features in new vehicles.

Not surprisingly, therefore, automotive radars are gaining attention for a variety of vehicle safety applications such as blind-spot detection, pedestrian detection, automatic braking, parking assistance and proximity warning. So far, short-range automotive radars, which support most of the above applications, have mostly been operating at 24 GHz frequencies, while long-range radars for applications like adaptive cruise control go for the 77 GHz band.

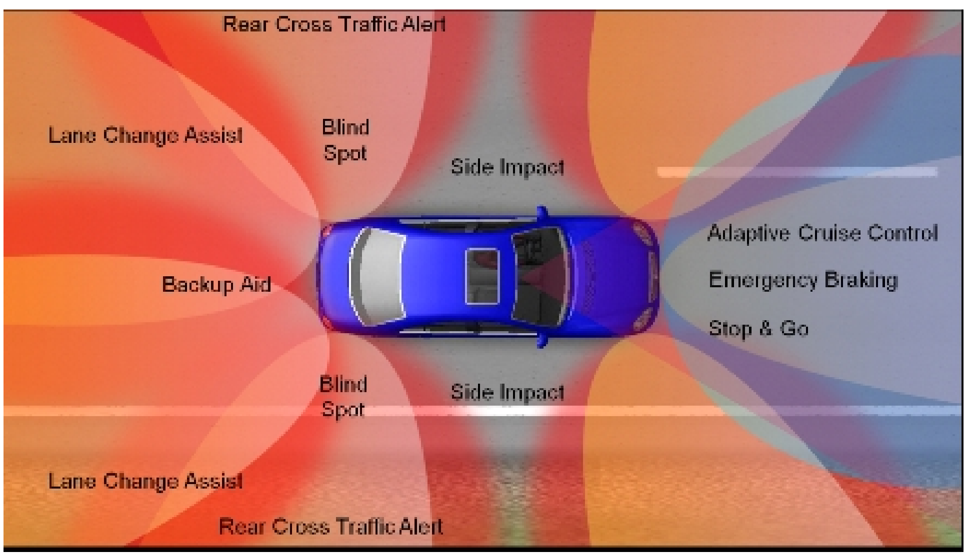

Figure 1: The embedded radars are key to the advancement of connected cars and autonomous vehicles.

However, there is a shift to higher frequencies of 76 to 81 GHz for both short and long-range radars for improved performance, smaller size and lower cost. Today's automotive radars at 24 GHz are rather large, while higher frequency bands like millimeter wave allow lighter radars that employ smaller boards and lower overall volumes while achieving equal or better radar performance. In addition, these smaller designs are easier to integrate into the automobile's body contour.

Moreover, smaller PCBs allow radar OEMs to bring down the cost for the automotive safety market that is widening, but also requires a competitive cost structure. Here, radar makers are increasing looking to single-board solutions that combine the RF and high-speed digital parts. However, such hybrid PCB designs will require RF optimized substrates next to low-cost FR-4 materials, and that leads to a number of manufacturability challenges.

Reliability is another key driver in advanced automotive safety systems like radars. The PCB construction should be thermally robust while showing consistent dielectric constant (Dk) and dissipation factor (Df) over varying humidity and temperatures ranging from -40°C to 85°C. Furthermore, automotive safety radars require larger bandwidths—up to 5 GHz—than other millimeter wave applications to acquire necessary exposure, so it's imperative that PCB materials are consistent over the entire bandwidth.

Polytetraflouroethylene (PTFE) materials, which have long been used for RF applications because of low Dk and Df, exhibit a crystalline structure that is affected by temperature changes and processing steps like sintering above the melting point. The shift in crystallinity leads to changes in effective density of PCB material, which in turn, results in changes in Dk. Moreover, PTFE materials show a highly variable coefficient of thermal expansion (CTE) that leads to high expansion at elevated temperatures.

Therefore, unlike other millimeter wave applications with more a controlled environment, such as mobile communications, for automotive safety radars, PTFE shows lower yield and processing difficulties at elevated temperatures, especially for hybrid constructions. This article takes a look at the new thermoset materials that boast high glass transition temperatures and high thermal reliability, and shows how these advantages make thermoset a viable alternative to PTFE dielectrics for automotive radar PCBs in terms of lower cost and higher reliability.

Thermoset's cost merits

Automotive OEMs are challenged with reducing costs, and one way to bring down the cost is using hybrid PCB constructions, where critical layers utilize the highest performance materials while other board layers can use standard FR-4 substrates. For such boards, PTFE materials are less desirable due to high costs, high CTE and a number of processing concerns.

For instance, PTFE uses abrasive fillers to lower CTE, and that increases the drilling costs. Such processing difficulties also result in limited compatibility in hybrid PCB designs. Moreover, high CTE in PTFE materials leads to critical issues such as dimensional deformation and residual stress.

On the other hand, thermoset polymers feature low processing and drilling costs because they don't require plasma de-smear and they don't use ceramic fillers to shorten drill life. Moreover, the fact that thermoset materials use the processing standard similar to FR-4 means that all the stacks and materials can be compatible with each other, a crucial benefit in hybrid PCB designs.

Figure 2: Hybrid constructions allow designers to reduce cost by employing expensive PCB materials for high-performance parts like RF and high-speed digital, while they can use FR-4 for non-critical layers.

One of the key goals in automotive design is to reduce the number of layers on the board and reduce the number of boards needed. Today, most radar applications use two boards, one for the high-speed digital processing and one for the RF circuitry. These two boards usually communicate through a connector, and automotive OEMs want to eliminate that connector for cost, size, and reliability reasons.

Moreover, the current PCB designs have the antenna on the outer layer using a connector, while the two boards are manufactured separately. Again, having just one board eliminates the need for the antenna connector. Automakers can significantly lower radar costs by combining the RF and high-speed digital processing in one board instead of two; they can put RF on one side of the stack and high-speed digital on the back.

Thermoset polymers are lower in price compared to PTFE materials. Furthermore, radar OEMs can lower the fabrication cost by using thermosets that exhibit very low-loss material properties while offering the processing capability that is similar to an FR-4 board. The board material for thermosets tends to drill very nicely.

Reliability: The creep factor
Another important factor that favors thermoset materials as opposed to PTFE in automotive safety applications like radars is creep rate. Creep is the permanent deformation that occurs due to thermal expansion at higher temperatures. The PTFE materials exhibit creep even at room temperatures, and that makes them less desirable for automotive environment that commonly operates at elevated temperatures.

PTFE's high degree of plastic deformation is especially a problem in the hybrid PCB designs where processing difficulties emerge while combining PTFE with the low-cost FR-4 material. Thermoset materials, on the other hand, display excellent electrical as well thermo-mechanical properties in prolonged exposures to high temperatures. Creep isn't an issue in thermoset materials even at temperatures as high as 200°C.

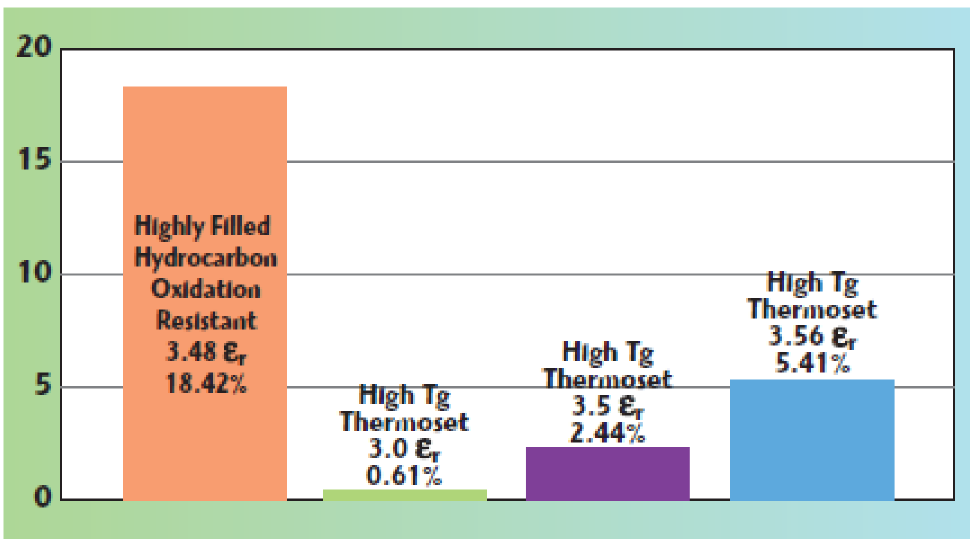

Figure 3: Percent change in dielectric loss after 1,000 hours of aging at 125°C is low for high Tg thermosets.

The high dimensional stability also means that yields and reliability are higher for high-frequency radar boards operating over a wide temperature range. Thermosets exhibit consistent Dk and Df over the entire radar bandwidth, and that provides consistent transmission line impedance and prevents phase distortion of RADAR transmit waveform due to frequency dependence on phase velocity.

There are more than 100 electronic control units (ECUs) in a vehicle these days, managing nearly every aspect of vehicle's operation. Not surprisingly, therefore, reliability is a key consideration for PCB designers in safety-conscious automotive electronics. The companies like Isola Group recognize the need for a cost-effective alternative to PTFE and other commercial microwave laminate materials to better serve the reliability aspects for advanced automotive safety and driver assistance systems.

Isola has unveiled a number of glass-reinforced thermoset materials to ensure superior thermal endurance across a wide range of elevated temperatures and thus to meet the highly demanding PCB material requirements of automotive radars.

Freescale design win

Freescale Semiconductor and RFbeam Microwave have conducted PCB materials evaluation for the joint development of a 77 GHz radar, and here, Isola's high Tg thermoset material Astra MT was reviewed for RF performance and processing advantages. Astra was found to show robust electrical as well as thermo-mechanical performance and compatibility with hybrid constructions.

Eventually, Astra MT material was selected for RF and antenna boards in Freescale's automotive radar demonstration kit. The ultra-low-loss Astra MT dielectric materials have demonstrated a very high suitability for patch antenna designs and RF front-end PCBs for 76 to 81 GHz radar applications, offering a higher yield and lower production costs.

The demonstration of the Astra MT material in Freescale's radar kit has also shown how easily thermoset polymers can be built in hybrid construction alongside a wide range of standard FR-4 materials to optimize cost. Moreover, from a reliability standpoint, Astra MT materials were thermally robust with a 200°C Tg and passed the rigorous tests like 6X 260°C to qualify for the automotive environment.

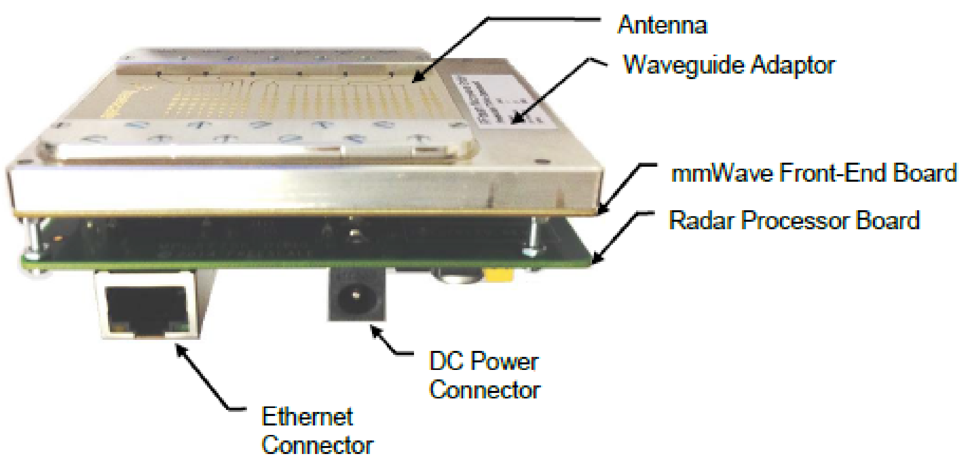

Figure 4: Freescale radar kit uses Isola's Astra MT material for RF circuitry.

Next up, for automotive radars operating at 24 GHz, where most of the action is right now for radar applications, Isola has released I-Tera MT materials for RF boards. I-Tera MT boasts stable electrical properties over a broad frequency and temperature range with a Dk that is stable between -55°C and +125°C up to 20 GHz.

Moreover, it exhibits a lower Df that is stable between -55°C and +125°C for up to 20 GHz, which makes I-Tera MT a cost effective alternative to PTFE and other commercial RF and high-speed digital laminate materials. Thermoset polymers like Astra MT and I-

Tera MT come with a full complement of laminates and prepregs to meet the diverse requirements of high-speed digital, RF and microwave designs.

Thermosets such as Astra MT and I-Tera MT fit nicely into automobile radars PCB requirements where OEMs are trying to bring down materials cost while raising the bar for reliability because it's important to have very high yields. These thermoset materials with performance optimized for higher frequencies are likely to play a crucial role in bringing the novelty of car radars to the mass market and thus help benefit a larger number of people.