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Titanium in Automobiles

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Titanium in Automobiles

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Abstract

Because of its high strength and low density, combined with virtual immunity to corrosion in the automotive environment, titanium offers many attractions for use in automobile applications. However, to date, use has mainly been in the sporting arena where the higher price of titanium compared to competing materials is not a major barrier. This paper will discuss racing and sports car applications of titanium; and very recent developments in which cost effective techniques have been used to produce titanium components for use in the family automobile.

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Introduction

The attractive characteristics (e.g., high strength, low density, and excellent corrosion resistance), of titanium offer many potential applications in racing cars, specialty vehicles and family automobiles – both in the engine/drive-train and in the body/chassis (1-6). In these applications, titanium offers the potential for weight saving often with performance improvements, when substituted for alloy or stainless steels, Figure 1 (7).

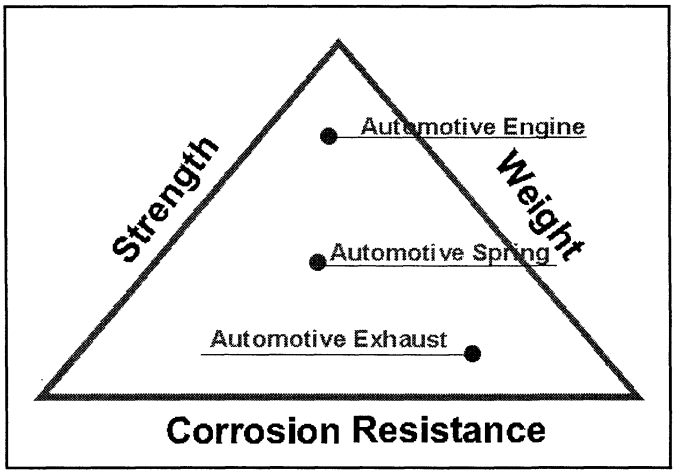

Figure 1. The Timet titanium triangle: automotive applications.

Timet identifies five keys to acceptance of titanium in automobiles, Table I. The racing market is the clear proving ground for use of titanium in automobiles. Here performance wins races, hence, racers will pay for performance. In racing, the "solution" is enhanced performance. Consensus is achieved by technology satisfying demand, whereby technology is leveraged. Most racing components are custom manufactured so titanium poses few changes to manufacturer techniques. Titanium component value is easily achieved, because the improved performance often provides the needed edge to win. The five keys to acceptance are readily achieved in this arena.

Table I. Five keys to acceptance of titanium in the production automobile.

- Provide a real solution
- Gain consensus
- Leverage technology
- Use established manufacturing techniques
- Deliver value

Titanium use in Automobiles

The enhanced performance desired from use of titanium in racing car applications significantly overrides the increased cost. For the high performance road automobile, the same argument can be made, but is more difficult to justify. For the family automobile, price reigns supreme. For a

number of years, racing-car engine builders have chosen titanium for reduced-weight valves and connecting rods because of the performance improvements from torque and power output and reduced deflection of associated components (6,7), Figure 2. Titanium is also the material of choice in mufflers and exhaust header pipes for racing motorcycles, Figure 3 (8).

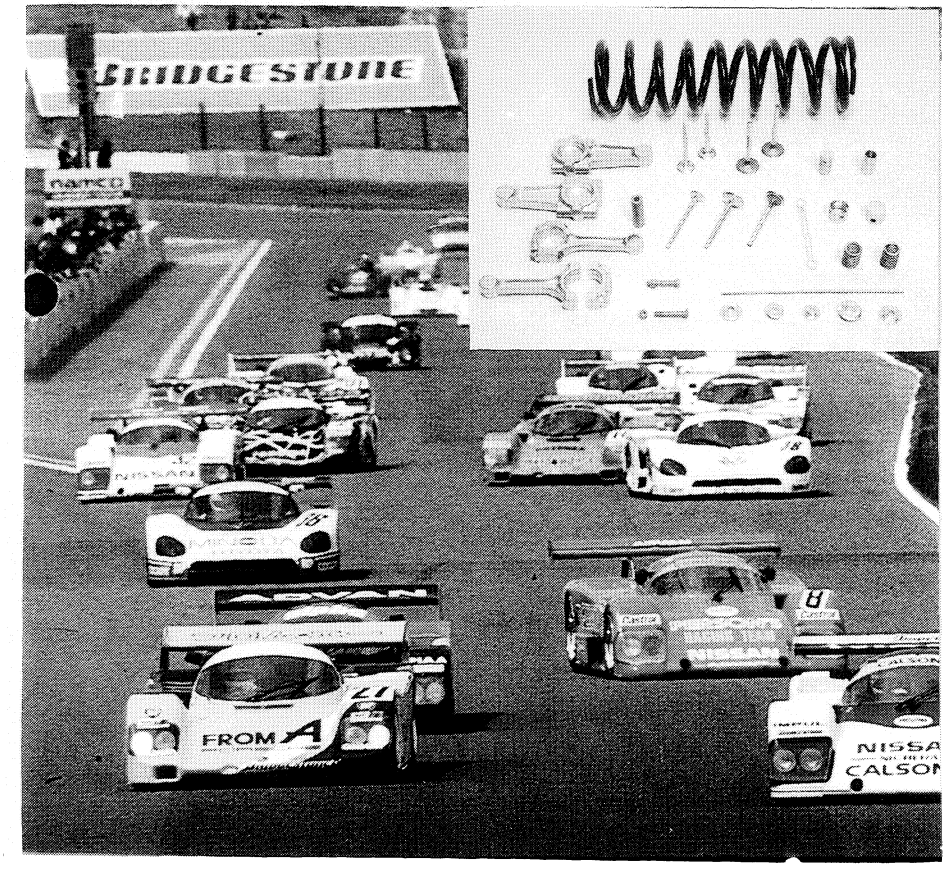

Figure 2. Various racing car components fabricated from titanium (6).

Figure 3. Motorcycle muffler made from titanium (8).

High performance specialty cars, which utilize lightweight materials to combine the performance of a track-only racecar with the driving pleasure of a road car such as the Saleen S7 also use titanium, Figure 4 (9).

In the family automobile, use of titanium would enable designs to achieve fuel economy (due to improved power-train efficiency or vehicle weight reduction), reduced engine noise and vibration, and improved durability due to reduced component loads (1-6). The effect of automobile weight on fuel consumption is shown in Figure 5.

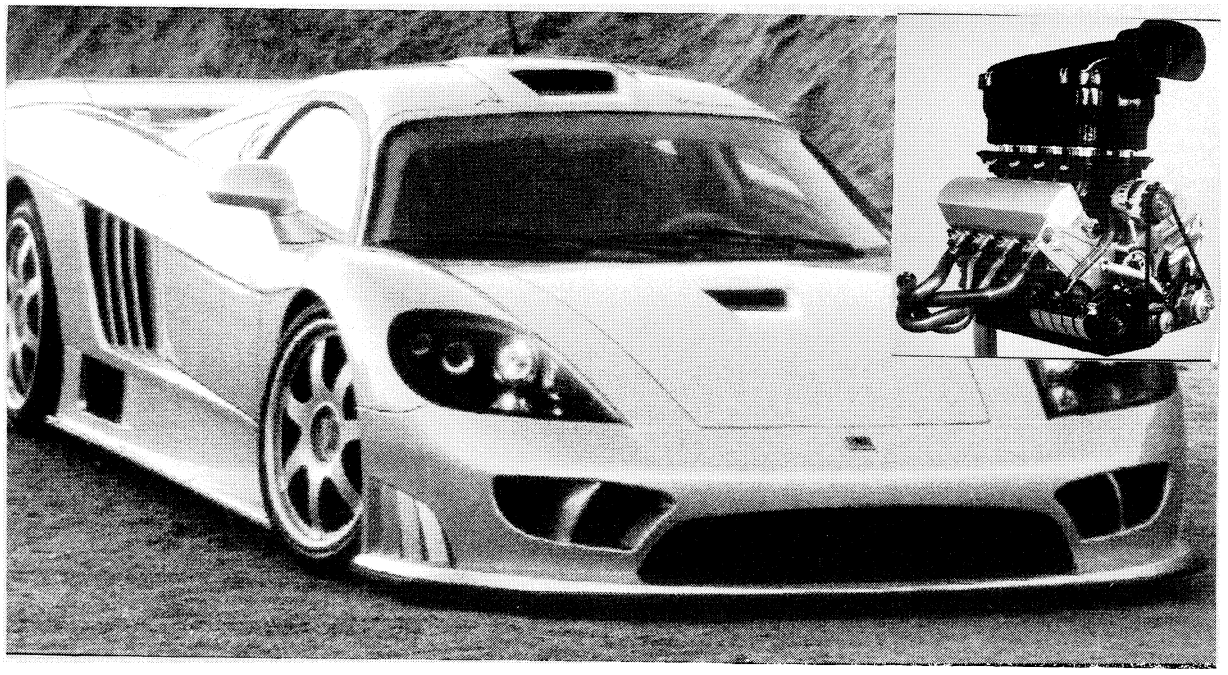

Figure 4. The Saleen S7 engine includes titanium valve spring retainers as well as other lightweight metals (9).

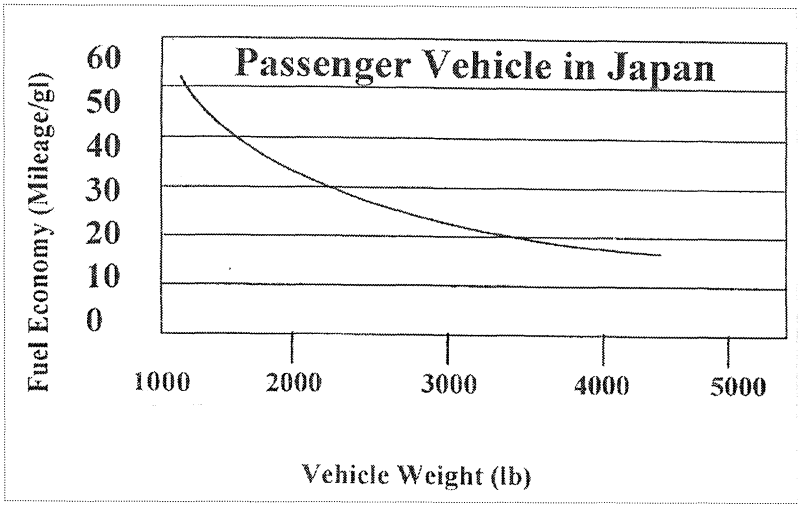

Figure 5. Effect of automobile weight on fuel consumption.

Production passenger automobile components which could benefit from use of titanium include engine valves, connecting rods and valve spring retainers, and valve springs, Figure 6. However, until recently use of titanium in the family automobile had not progressed beyond the prototype stage because of the high cost of titanium compared to competing materials. There are two major obstacles that must be overcome of titanium is to be used in high-volume production

automotive applications. (1) First: both raw material and component fabrication costs must be reduced to affordable levels. Second: an appropriate supply base must be created, i.e., the capabilities of titanium and component suppliers must be expanded to provide the volume of material and products that would be needed.

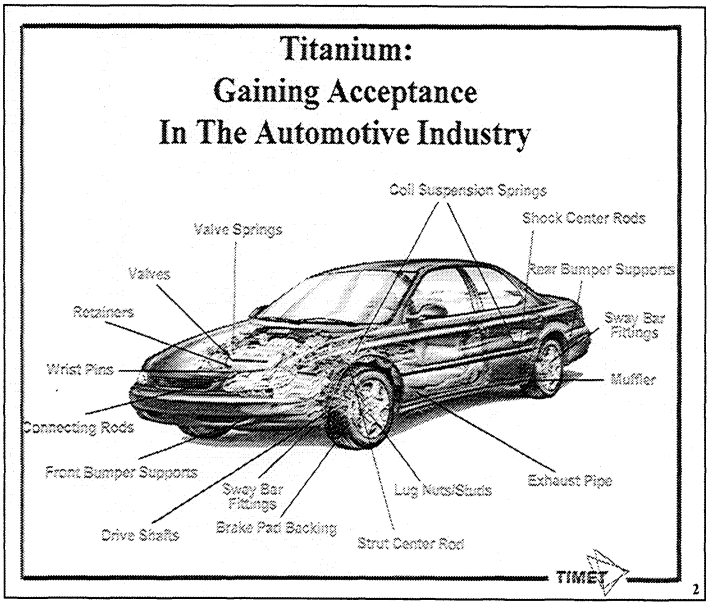

Figure 6. Potential applications of titanium in passenger cars.

The first use of titanium in an albeit high end production automobile was for connecting rods in the Acura NSX V-6; this use has been bill-of-materials since the vehicle was introduced in 1991. Other notable applications, also in Japan, are titanium valves in the 1998 Japanese car of the year, the Toyota Altezza (Figures 7) and titanium gear shift knobs, in Honda's S2000 Roadster (Figure 8), and Acura's Integra Type R's. In Europe, Ferrari, and starting in 1999 Porche, have adopted titanium connecting rods in series production models.

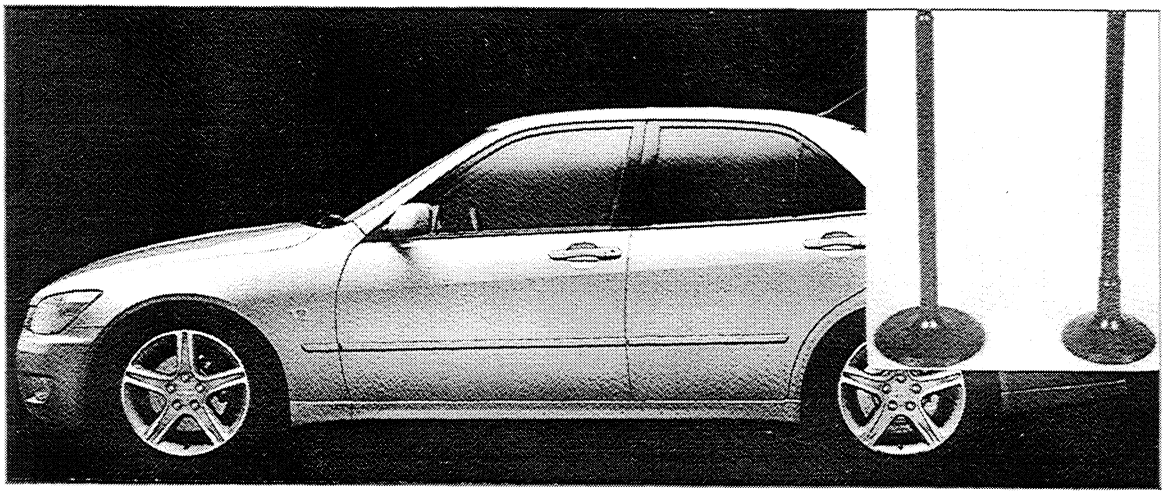

Figure 7. The Toyota Altezza, 1998 Japanese Car of the Year, the first family automobile in the world to feature titanium valves. Ti-6Al-4V intake valve (left) and TiB/Ti-Al-Zr-Sn-Nb-Mo-Si exhaust valve (right). (Courtesy Toyota Central R & D Labs, Inc.).

The world-wide titanium market is about 100M lbs per year, with about half in the USA. The total production car market is 60M vehicles with slightly over 25% in the USA. Thus, even 1lb of titanium in 50% of the autos would represent a substantial 30% increase in titanium use. Thus the auto use of titanium has often been referred to as the "holy grail" of the titanium industry.

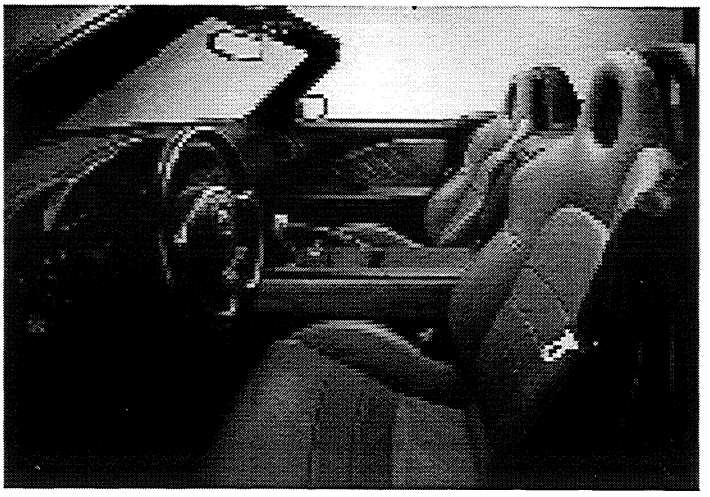

Figure 8. Titanium gear-shift knob on the Honda S2000.

Recent Developments

The two most recent applications of titanium in family autos demonstrate the importance of the five keys to acceptance shown in Table I. The first of these is the Corvette Z06 exhaust where the goal was to reduce mass to improve performance. Titanium provided a 26 lbs dual muffler assembly, 41% weight reduction, contributing to the best performing Corvette ever with a virtually unlimited exhaust life, Figures 9 and 10.

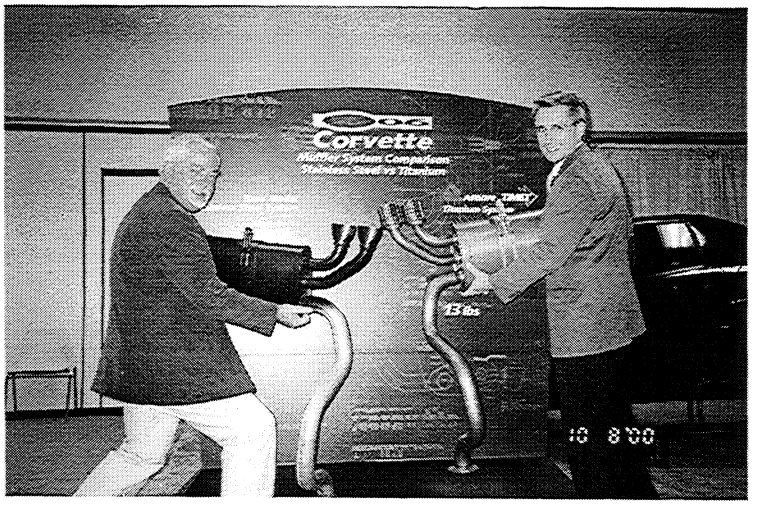

Figure 9. The authors (F.H. (Sam) Froes, left, and Kurt Faller, right) lifting the stainless (left) and titanium (right) exhaust systems.

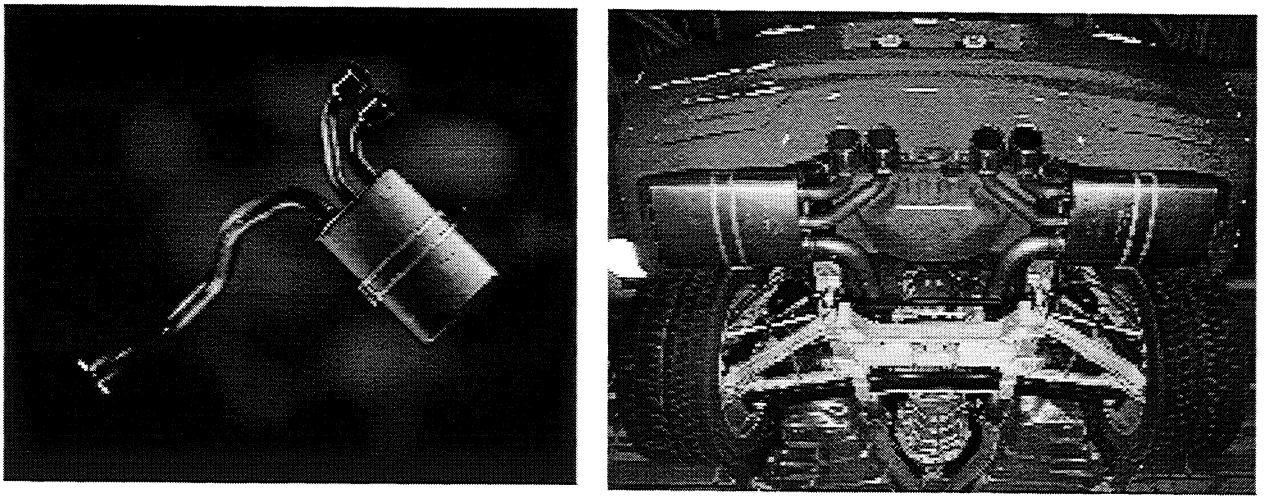

Figure 10. The Corvette special edition ZO6 twin titanium exhaust system (left) and shown in place (right).

Consensus and leverage were achieved by Timet working with Arvin Meritor on a new Timetal Exhaust grade™ titanium (similar to Grade 2) with enhanced surface conditioning by Timet and an innovative design by Arvin Meritor; and jointly new testing methods were developed to assure performance. Established manufacturing techniques for stainless steel stamping, bending, cold forming and welding were successfully modified for titanium. And finally the mass reduction noted above delivered the desired customer value.

Springs are a natural application for titanium because of its low modulus and reduced density compared to steel. Titanium springs are already extensively used in the aerospace industry by companies such as Boeing. However, Timet felt that the product was much too expensive for automobile use. Thus, the approach here has been to develop the titanium auto springs with an aerospace manufacturer and then, along with Volkswagon AG, take the spring to be fabricated by a car producer's fabricator using a standard steel spring manufacturing line. VW's chosen fabricator, Muhr and Bender, modified their steel spring manufacturing line to accommodate titanium. The result, using the low cost beta alloy (Ti-4.5Fe-6.8Mo-1.5Al) is a material up to 50% less expensive than conventional beta alloys, a spring only one-third the mass of an equivalent steel spring, and a spring with optimized fatigue life (Figure 11). The use of these titanium springs on the 2001 model year Volkswagen Lupo FSI contributes to the 180 pound overall weight reduction on the FSI model compared to the standard model Lupo. The Lupo FSI is being marketed in Europe as the lowest fuel consumption gasoline car in the world at 48 mpg. Volkswagon expects to manufacture up to 3,500 of the 2001 model year FSI Lupos.

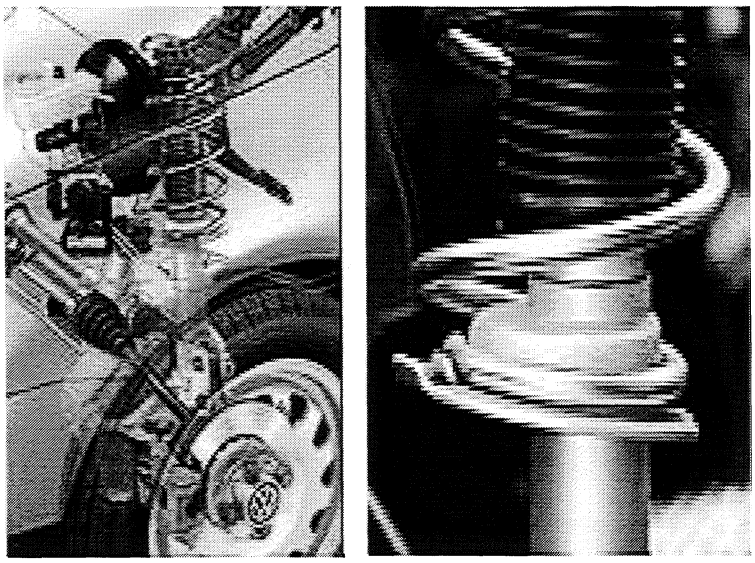

Figure 11. Titanium springs on the Volkswagen Lupo FSI.

Future Opportunities

The critical break through appears to have been made in getting titanium into large volume production automobiles in niche applications. Clearly, titanium sheet is not going to replace steel sheet with a cost differential of 50-100 times (1). However, the niches applications already established can be grown through design and production advances, and new niches can be added. The challenge will be to move beyond the niche status to large volume applications by reducing cost. The applications discussed above offer insights into how costs can be reduced. Lower cost sponge would be very desirable, but whether the Kroll or Hunter processes (already "optimized" extensively) can be modified to achieve this is frankly doubtful; but the Fray process (10-12) offers a completely new, albeit still experimental, technique with interesting potential. Near net shape (NNS) powder metallurgy approaches have proved their potential on the Altezza, and other "chunky" parts are also amenable to this method (13). Lower cost, higher yield alloys and single melt (cold hearth electron beam or plasma) processing can reduce cost; as can the implementation of multi-year price agreements. The titanium industry must also be prepared to use available high-volume steel production equipment and assure auto manufacturers that consistency and quality are not problems.

Concluding Remarks

Titanium has established a foothold in the automobile industry. This must now be expanded by the titanium industry transforming itself to realize the promise of mass-market automobile applications – and follow the five keys noted in Table I.

Acknowledgements

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