Dual Space Technology Transfer

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Abstract. Over the past fifteen years, MER has had several NASA SBIR Phase II programs in the area of space technology, based upon carbon-carbon (C-C) composites. In addition, in November 2004, leading edges supplied by MER provided the enabling technology to reach a Mach 10 record for an air breathing engine on the X-43A flight. The MER business model constitutes a spin-off of technologies initially by incubating in house, and ultimately creating spin-off stand alone companies. FMC was formed to provide for technology transfer in the area of fabrication of C-C composites. FMC has acquired ISO 9000 and AS9100 quality certifications. FMC is fabricating under AS9100 certification, flight parts for several flight programs. In addition, FMC is expanding the application of carbon-carbon composites to several critical military programs. In addition to space technology transfer to critical military programs, FMC is becoming the world leader in the commercial area of low-cost C-C composites for furnace fixtures. Market penetrations have been accomplished in North America, Europe and Asia. Low-cost, quick turn-around and excellent quality of FMC products paves the way to greatly increased sales. In addition, FMC is actively pursuing a joint venture with a new partner, near closure, to become the leading supplier of high temperature carbon based composites. In addition, several other spin-off companies such as TMC, FiC, Li-Tech and NMIC were formed by MER with a plethora of potential space applications.

Keywords: C-C Composite, Coatings, Nanotechnology
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INTRODUCTION

Materials and Research Corporation (MER), through Small Business Innovation Research (SBIR) contracts with NASA has contributed a number of technologies to record-breaking Mach 10 flight. These contracts have been with NASA at Langley Research Center, Marshall Space Flight Center, Johnson Space Center, Goddard Space Flight Center and Jet Propulsion Laboratory. Through SBIR contracts, MER has developed thick, high thermal conductivity composites with oxidation protection at extremely high temperatures. Using MER's oxidation protected C-C composite leading edges, the X-43A flight reached Mach 10 in November 2004.
The technological success was possible by the SBIR funds.

MER'S SUCCESS STORY – X43A

Leading edges are the essential parts for the X-43A experimental aircraft, as well as for other aircraft and space vehicles. As the vehicle travels through the earth atmosphere, the leading edges are subjected to the highest temperature and thermal loads. The heat and thermal loads increase as the vehicle's speed is increased. For the X-43A test vehicle, the temperature reaches 4000^{o}F, which is higher than that which the space shuttle experiences during reentry into the earth's atmosphere. The requirements for the leading edges included light weight, high thermal conductivity and oxidation protection at 4000^{o}F. MER selected the P-30X fiber, which reached the necessary thermal conductivity after heat treatment at temperatures above 4500^{o}F. Several thick C-C composites were manufactured using a patented C-C composite process and then were densified, using a liquid matrix infiltration process, which resulted in good mechanical and thermal properties. The dense, very high thermal conductivity of C-C composites were machined to drawings specifications. As a final step, MER achieved oxidation

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protection at 4000°F, by using sequential chemical vapor reaction and chemical vapor deposition processes. MER manufactured all of the leading edges for the X-43A, which are shown on the test vehicle, Figures 1 and 2.

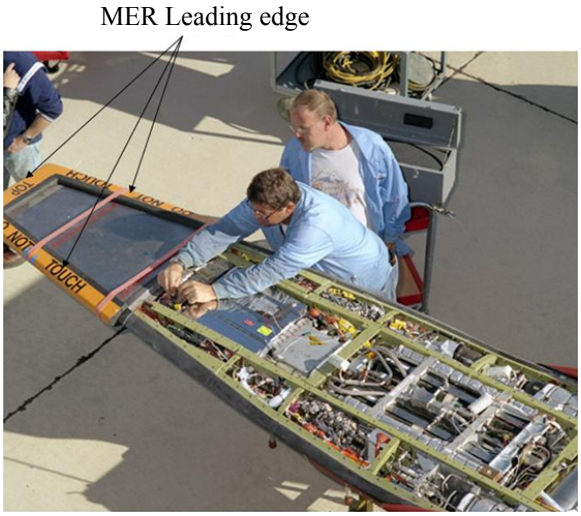

Figure 1. NASA technicians assemble the scramjet-powered X-43A Test Vehicle before its record Mach 9.6 Flight.

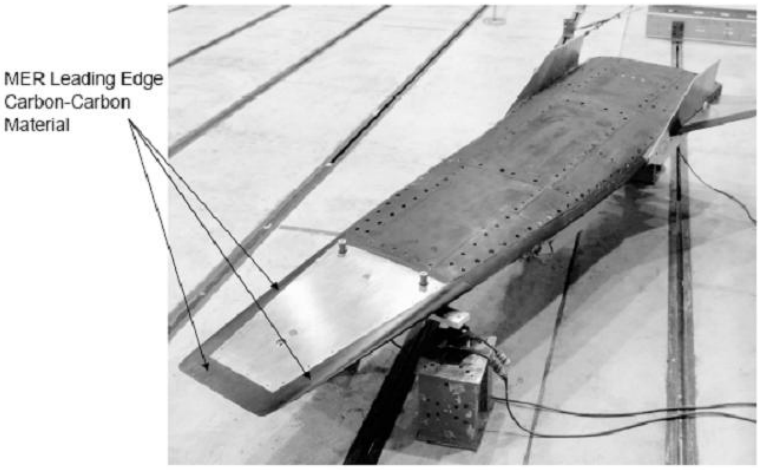

FIGURE 2. MER Leading Edges Mounted on X-43A Test Vehicle.

In addition to the leading edges, MER also fabricated the fasteners, in this case C-C bolts, used to hold the leading edges to the rest of the X-43A flight vehicle at extremely high temperatures.

MER'S SPIN-OFF COMPANY, FMC

Frontier Materials Corporation (FMC) is a spinoff company of MER. FMC uses MER's patented C-C composite process to prepare low-cost PAN (polyacrylonitrile)-based fiber and pitch-based fiber composites for commercial, military and aerospace markets. The properties of FMC's C-C composites include high strength, light weight and operation at very high temperatures when oxidation protected. FMC's composites can be made with either low or high thermal conductivity or with high electrical conductivity. The C-C and also some SiC-SiC composites are being used in heating fixtures, structural flat panels, brakes, panels and many other applications. Examples of FMC produced products are given in Figures 3 - 5.

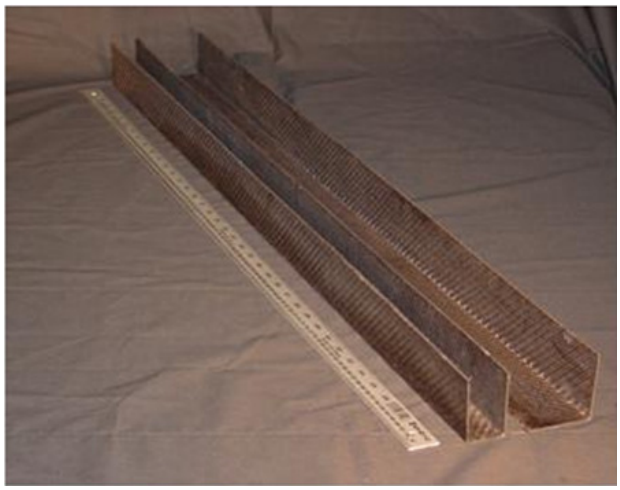

Figure 3. U's and L's for Commercial Applications.

Figure 4. Stators for Military Applications.

The C-C composite L's and U's, Figure 3, are produced in moderate volume for commercial customers. The stators, Figure 4, which are used for a high technology motors are liquid infiltrated to increase oxidation resistance.

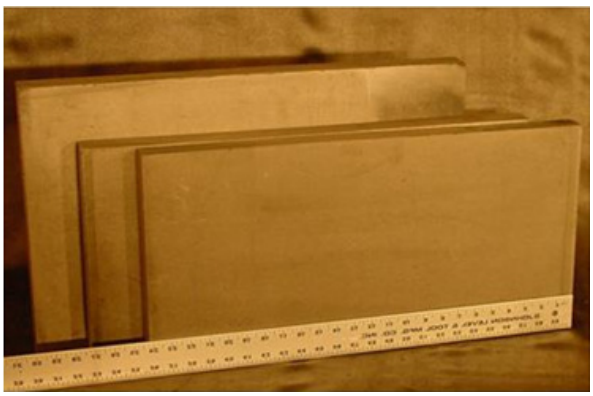

Figure 5. Large, Thick C-C Plates, After Cutting.

Figure 5 shows the large C-C plates for furnace fixtures, which are used by world-wide customers. In addition, FMC is in the process of commercialization of several composite technologies for military space applications, based upon X-43A success.

OTHER SPIN-OFFS

MER has developed several other commercial spin-offs. LiTech is a commercial spin-off devoted to Lithium-ion batteries. FIC is the commercial spin-off devoted to fullerenes technology. Also, NMIC is the commercial spin-off devoted to nanotechnology.

Figure 6. C-C Composite Lithium-ion Battery – 21 Amp Hour Charger.

Figure 7. C-C Composite Lithium-ion Battery – 2.2 Amp Hour Wing Cell.

Figures 6 and 7 show the advanced battery technology developed by MER's spin-off, Li-Tech. Space exploration applications are currently being explored.

Figure 8. FCC Fullerene Plant in Japan – 40 Metric Tons per Year.

Figure 8 shows the technology transfer by MER via FIC for the biggest fullerene plant in Japan. Numerous space applications were explored. In the nanotechnology area, MER is currently pursuing nanotechnology applications. A MER spin-off, NMIC has looked at some space applications.

COMMERCIALIZATION PER INVESTMENT CATEGORY

There are several forms of investments made into the commercial spin-offs. They include: direct sales, direct investment by the partners and indirect investment. Figures 9 – 11 show the actual commercial revenue.

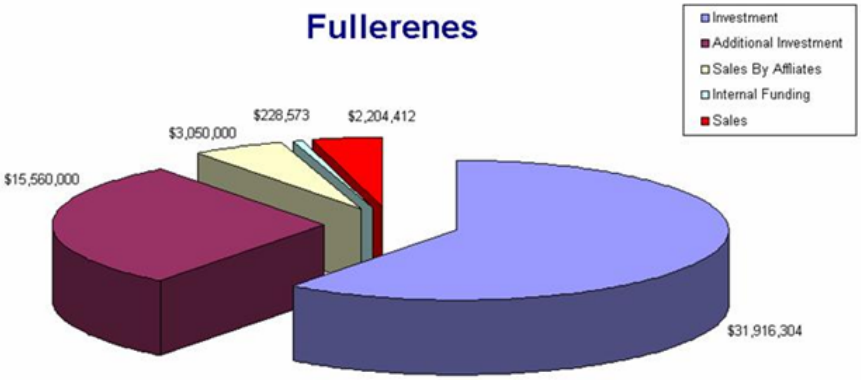

Figure 9. Pie Chart of Fullerene Commercialization per Investment Category.

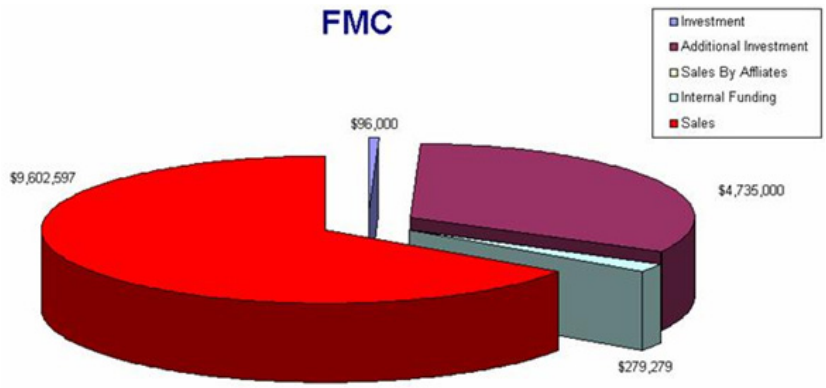

Figure 10. Pie Chart of FMC Commercialization per Investment Category.

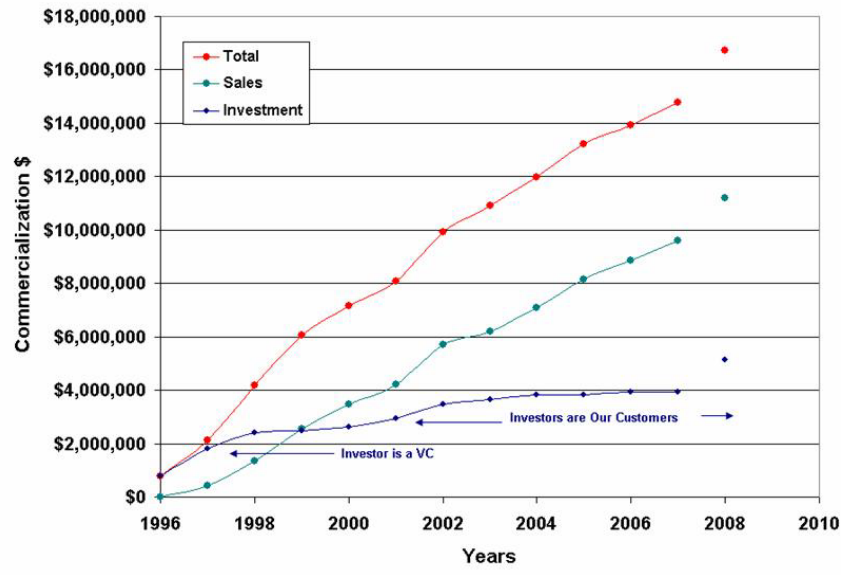

Figure 11. FMC Commercialization ($) for 1996 to 2008.

CONCLUSION

FMC has produced thick, oxidation protected, very high thermal conductivity C-C composites for military and aerospace applications. The FMC technology was the critical element to the success of the X-43A flight test. Also, using MER's patented C-C composite process, FMC has produced low-cost PAN-based composites with a 50% reduction in manufacturing cost and a 70% reduction in processing time. Finally, FMC has pioneered the manufacturing of SiC-SiC and other composites for commercial, military, government and aerospace applications. Other space spin-offs are possible in the near future.