

IMPROVED FORM OF VAPOR-GROWN CARBON FIBER

Jason R. Guth

Applied Sciences, Inc.
Cedarville, OH 45314, USA

INTRODUCTION

Vapor-grown carbon fiber (VGCF) has been produced only in small quantities due to the batch growth method. This fiber, alone and in composites, has demonstrated record high thermal conductivities. In order to become a commercially viable material, the production cost must be significantly reduced. Thus, an effort is being undertaken to reduce both the batch nature and the labor involved in the process.

VGCF growth involves nucleation of graphitic filaments from catalytic particles followed by thickening to the desired diameter. At ASI, the catalyst is sprayed onto carbon substrates a number of which are placed into a tubular reactor similar to the process of Tibbetts[1]. After cooling down, the fiber is manually harvested from the substrates as self-supporting sheets. These sheets are also of finite length and, thus, can not be used for weaving, filament winding, etc.

A related product has been developed which involves the deposition of pyrolytic carbon onto continuous carbon fiber substrates[2]. This hybrid carbon fiber has the advantages of a continuous form and a high thermal and electrical conductivity due to the highly graphitic coating. However, due to the slow growth rate of carbon, it is difficult to obtain a uniform, thick coating on all filaments within the tow without filament bridging.

In order to overcome these difficulties, a substrate similar to both the reusable carbon boards currently used and continuous carbon

fiber tows has been investigated as a substrate for VGCF growth. This substrate is a carbon fiber non-woven mat. In a manner similar to the hybrid carbon fiber, the PAN fibers in the paper substrate will be coated with pyrolytic carbon while the VGCF are growing. The resulting product will be a sandwich structure with a low density PAN fiber core coated with pyrolytic carbon and with VGCF fiber mats on each face of the sheet. This paper substrate can be essentially endless, can become part of the product, and does not require labor intensive VGCF harvesting.

EXPERIMENTAL

Non-woven carbon fiber paper mats [3] were substituted for the normal, reusable substrates. These mats were treated identically to the reusable substrates and VGCF was grown on the paper substrates as described above. A number of these paper mats with the VGCF grown on both sides were stacked and heat treated to 2900°C for at least 15 minutes. The mats were then cut to size and molded in a hot press with an epoxy resin cured at 250°F. The mats were oriented such that the VGCF on the surface of the paper substrates was unidirectionally oriented and defined as the composite x direction.

RESULTS

Measured properties of the VGCF/paper composites are shown in Table 1 and compared with similar VGCF composites. Due to the paper substrate, the volume fraction of VGCF which can be incorporated into the composite is limited. Thus, the thermal conductivity can not be as high as that with only VGCF fiber.

It has previously been demonstrated that the composite thermal conductivity is a linear function of the VGCF volume fraction in the composite. Attempts are being undertaken to produce thinner paper substrates from smaller and more graphitic fiber, such as Pyrograf-III VGCF[4].

Unlike the VGCF grown and harvested from a substrate, the material used in this study contains a core of essentially planar isotropic orientation. This isotropic pyrolytic carbon coated PAN fiber core serves as a constraining layer as evident in the reduced y direction CTE of this composite. The x direction CTE has also changed from a negative to a positive value.

The use of other than unidirectional fiber architectures should allow for more control over the composite CTE.

CONCLUSION

It has been demonstrated that VGCF can be grown on both sides of carbon fiber paper substrates. Composites can be fabricated from this material without manual harvesting of the VGCF from the substrate, the substrate becomes a part of the product. While the ultimate thermal conductivity of the composite is not as high as for traditional VGCF reinforced composites, it is still very respectable for an epoxy matrix composite.

Table 1. Composite properties.

Fiber	Vol. %	K_x	K_y	CTE_x	CTE_y
		W/mK		ppm/°C	
This Work	62	304	126	2.2	10.5
VGCF 1D	54	466	142	-1.5	18.0
VGCF 2D	55	303	284	2.0	6.3
VGCF	75	661	37	nm	nm

The benefits of eliminating manual fiber harvesting, the possibility of producing material in continuous lengths, and the possibility of more nearly isotropic CTE control overcome the slight reduction in ultimate thermal conductivity. Important applications include electronic heat sinks with a requirement for both high thermal conductivity (greater than aluminum) and a CTE close to silicon or gallium arsenide.

Future work will focus on reducing the thickness or volume fraction of PAN fiber cores or replacing the PAN fibers with more graphitic fibers. Development of papers from Pyrograf-III VGCF is particularly attractive.

REFERENCES

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