**Carbon Fiber Integrated MEMS for Optical Scanning**

**CNF Project # 1241-04**

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**Abstract**

Optical scanners are used in a variety of systems to transmit or convert information encoded in light. Employed in telecommunications networks, optical storage systems, projection displays and image recording systems remain critical components that have not seen the miniaturization and cost and performance improvements as other optoelectronic devices. The development of microelectromechanical systems (MEMS) technology, has promised inexpensive, very low power requirement, miniature scanning mirrors capable of very high speed scans and large deflection angles. However, the mechanical property limitations of traditional materials used in MEMS technology has failed to produce scanners that can simultaneously scan large angles (mechanical angles $> \pm 45^\circ$) and high speeds (5-100 KHz).

We have developed a novel category of MEMS optical scanners that make use of fibrous materials—in particular high performance carbon—as mechanical elements, cultivating the development of a novel, more robust MEMS material category capable of fatigue free behavior and vastly superior elastic deformations. Carbon fiber integrated MEMS optical scanner devices have been successfully fabricated leveraging existing semiconductor and MEMS processing, and exhibit fatigue free mechanical scans of $> \pm 45^\circ$ at speeds exceeding 5 kilohertz (KHz).

**Summary of Research**

The goal of this project is to develop a novel materials technology based on fibers to address the mechanical limitations of the current silicon-based MEMS technology with a particular emphasis on high performance applications that place severe demands on materials performance, such as optical scanners. The use of fibers in MEMS scanner devices permits the use of very high performance materials that can be tailored towards the performance needs of the device. By using fibers as the flexure elements within a MEMS micro-mirror, specific property enhancements can be obtained with virtually limitless control of the strength and stiffness of the flexures resulting in enhanced speed and scan angle performance of the MEMS scanner device. The large bending capabilities of fibers even at micro-scales permits the creation of micro-mirror elements with very large deflection capabilities, resulting in scan angles far surpassing existing silicon based devices. Additionally, by simply varying the number of fibers within a flexure element the speed response of the micro-mirror can be modified, without any change in the large scan angle capability. The carbon fiber integrated MEMS micro-mirror technology developed through the present research also shows greater resistance to fatigue due to cyclic stresses [1].

We have developed reliable methods to deposit precise numbers of oriented layers of fibers onto silicon substrates, and have developed methods to lithographically pattern and etch the fibers into desired MEMS structures. Etch chemistries optimizing fiber etch rates ($> 0.7 \, \mu m/min$) have been developed [2]. Epoxy and metal based coupling agents have also been explored to form composite structures coupling the carbon fiber flexure elements to silicon structures on the substrate. Surface treatments to enhance the coupling of fibers to both thin film metallic matrices and photo-curable epoxy based materials have also been developed.

Using carbon fibers integrated with silicon structures, we have successfully developed a novel MEMS micro-mirror technology capable of scanning laser beams at very fast speeds and large scan angles. This performance behavior has been extended towards a prototype miniature projection system capable of scanning an 8” x 11” monochrome video image from a 1.5” projection distance.
Figure 1: A MEMS micromirror supported by carbon fiber flexures with 10 fibers in each flexure.

Figure 2: Optical scan performance of carbon fiber MEMS scanner at 2.5 KHz, showing 160° scan capabilities.

Figure 3: Carbon fiber MEMS micromirror with 4 flexures.

Figure 4: Optical scan performance of 4 carbon flexure scanner at 5 KHz, demonstrating a linescan of 9” from a 1” projection distance.

References
