1 Introduction
The main goal of this work is to provide a direct method to assess the compressive properties of high performance carbon fibers at the microscopic scale. Reliable mechanical testing at the microscopic scale can provide unique information regarding the effect of intermolecular interactions\cite{1} which can not be generated by traditional compressive tests of unidirectional composite performed at the macroscopic scale. The small diameter of the carbon fibers which is usually less than 10 $\mu$m, cause difficulty in measuring the axial compressive strength. Several techniques have been proposed including the loop test\cite{2}, the recoil test\cite{3-5}, the micro compression test\cite{6-9}, compression test of a single-fiber composite\cite{1,10} and estimation from the compressive strength of a unidirectional composite. In the loop test, a compressive stress is produced by bending the fiber into a loop. Thus, the compressive stress is not uniformly distributed in the fiber cross-section and a tensile stress arises in the convex side of the fiber. With the recoil test, a compressive stress is produced in the recoil process which takes place after a pre-tensioned fiber is cut between fixed ends. Lateral displacements imposed on the fiber when the recoil process is initiated cause flexural fracture\cite{4}, and viscous damping in the fiber and at the fixed ends of the fiber affects the results\cite{3}. In addition, the tested fiber should be sufficiently stronger in tension than in compression. In a compression test on a single fiber composite, residual stresses imposed on the fiber due to matrix shrinkage affect the results. In the axial compression test of a unidirectional composite, the stress fields are much more complicated and the precise fracture mechanism should be elucidated in order to relate the compressive strength of the composite to that of the component fibers. It is possible that even if the composite appears to fracture in compression, the component fibers are fractured in flexure microscopically. Thus, in view of applying a true axial compressive stress to a single fiber, the micro-compression test, in which the fiber is directly compressed, is the most suitable.

In the present study, focused ion beam is used to cut fiber column from fiber reinforced epoxy resin composite, Nano indentation instrument with the addition of a flat tipped indenter having a diameter larger than the fiber diameter is used to apply a uniform axial compressive load on the fiber.

Materials and experimental procedures
The PAN-based carbon fibers used in this study are indicated in Table 1 together with their tensile properties. The “T series” fibers have considerably improved tensile strength, whereas the “M series” fibers have much higher tensile moduli. The data are official values provided by the manufacturer (TORAY Co. Ltd). The composite bulk with a circular cross-section were prepared as follows. A bundle of carbon fiber was soaked in liquid epoxy resin and was left for 8 hours at room temperature. The polishing process involved wet 1000 and 2000 c emery cloth followed by 0.3 $\mu$m wet polishing alumina suspensions.

Fig.-1 surface of the bulk section of composite

2.2 experimental procedures
The micro-compression sample preparation process consists of two steps. First, the surface of the bulk section(fig.-1) is oriented normal to the FIB column,
and an area of fiber is located using FIB imaging. In that area a series of concentric annular milling patterns are used to mill a cavity or crater that creates each sample blank in relief, as shown in Fig. 2.

Fig.-2 micro-compression sample and surrounding cavity

A new analytical technique to perform a fiber micro-compression test has been developed based on the nano-indentation. This system, can measures the force and displacement applied by an indenter on a fiber. A flat tipped indenter having a diameter larger than the fiber diameter (Fig. 3), which is used to apply a uniform axial compressive load on the fiber.

Fig.-3 SEM images of the top surfaces of micro-samples

4. Result and discussion

Results of experiment showed in fig.-4.

Fig.4 relationship figure of displacement vs. load

5. Conclusion

A new micro-mechanical technique capable of applying an axial compressive load on a segment of free fiber has been developed. Methods of focused ion beam milling is used for specimen preparation, a direct measure of the axial compressive modulus of high performance carbon fibers is obtained. The methodology allows one to easily probe for size effects that are linked to the physical dimensions of the deforming volume. This methodology was demonstrated through testing of a single carbon fiber. References