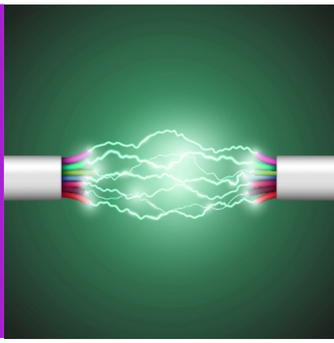
KLA INSTRUMENTS

Concurrent Conductivity and Nanomechanical Properties Measurement of Pyrolytic Carbon (PyC) using the I-V Option



Introduction

The electromechanical properties of semiconductor materials (MEMS, micropillars, cylindrical bumps etc.)[1] have been subject to extensive investigation due to their importance in device design. A fundemental understanding of the phenomena that are induced by mechanical deformation, such as piezoelectric response, phase transformation and dielectric breakdown, as well as their effects on electrical performance will benefit product design, integration, etc. To futher this study, the KLA Instruments™ nanoindentation systems may be configured with the **I-V** Option. The I-V option integrates complementary measurement techniques to allow simultaneous mechanical and electrical characterization. This work examines use of the I-V option on Pyrolytic Carbon (PyC).

Materials and Methods

The experiments were performed using the I-V option on an iNano® system. The I-V option, shown in Figure 1, includes an external picoammeter/voltage source meter (Keithley Model 6517B), a conductive indenter tip and the integrated InView I-V controller. A command is sent from the InView controller to the external picoammeter/voltage source to apply a voltage to the sample, with InView recording the resulting circuit current. This integration enables the in situ characterization of both the mechanical and electrical responses of the sample.

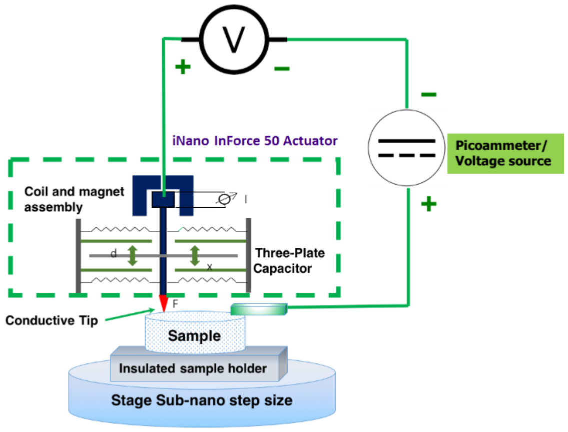


Figure 1. I-V option schematic.

A conductive tungsten carbide Berkovich tip was used for the conductivity measurement while simultaneously performing nanoindentation testing. Pyrolytic carbon was the sample for which the electromechanical properties were measured. The experiment details are listed in Table 1.

Table 1. Sample and test protocol information

Sample	Pyrolytic carbon
Surface Preparation	2000 grit abrasive sandpaper polish
Tip	Conductive tungsten carbide
Test Method	I-V electromechanical measurement
Source Voltage	0.05V
Indentation Depth	450nm
Number of tests	10

Results and Discussion

The typical indentation load-depth curve for the PyC sample is shown in Figure 2. The pure elastic deformation observed in this curve is caused by the unique structure of PyC. The strong interplanar C-C bonds (sp2) exist in the a-b plane and the weak interplanar van der Waals force is along the c-axis[2]. Figure 3 shows a diagram of the PyC molecular structure.

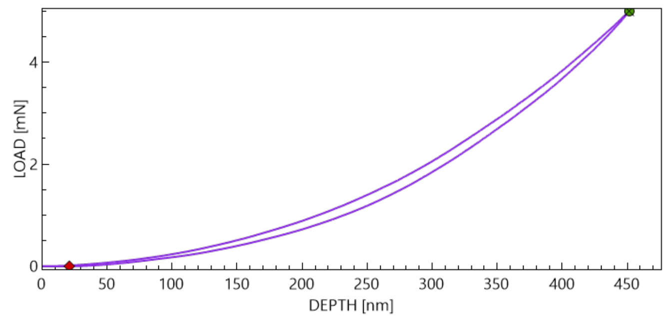


Figure 2. Typical indentation load-depth curve for the PyC sample.

Figure 4 shows the in situ electrical conductivity measurements of PyC, where (a) plots the conductance as a function of time and (b) plots the resistance and a function of time. The increase in conductance during indentation loading is caused by the increase in contact area between the tip and the underlying sample. The elastic recovery of PyC (Figure 4c, right side of curve) during unloading results in the smooth decrease in both current (Figure 4d) and conductance (Figure 4a). The ten repeated curves trace each other very well, showing good measurement repeatability for the PyC sample.

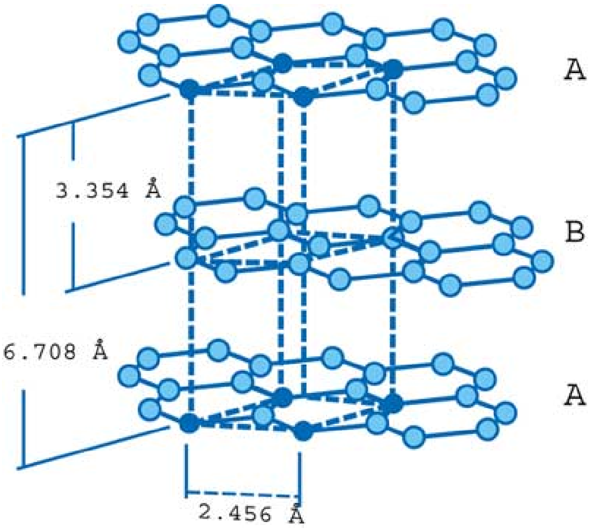


Figure 3. Structure of graphite crystal[2].

Conclusions

The KLA Instruments iNano nanoindentation system configured with the I-V option was used to investigate the electromechanical properties of pyrolytic carbon, with the results showing that pyrolytic carbon exhibits linear current-voltage characteristics. The I-V option can be very beneficial for the measurement of electromechanical properties for a wide range of materials.

References:

1. Diobet, M., "Characterization of microdevices by nanoindentation," Nanoindentation in Materials Science, J. Nemecek (ed.), InTech (2012). https://doi.org/10.5772/50997
2. https://www.electronics-cooling.com/2001/08/the-role-of-natural-graphite-in-electronics-cooling/

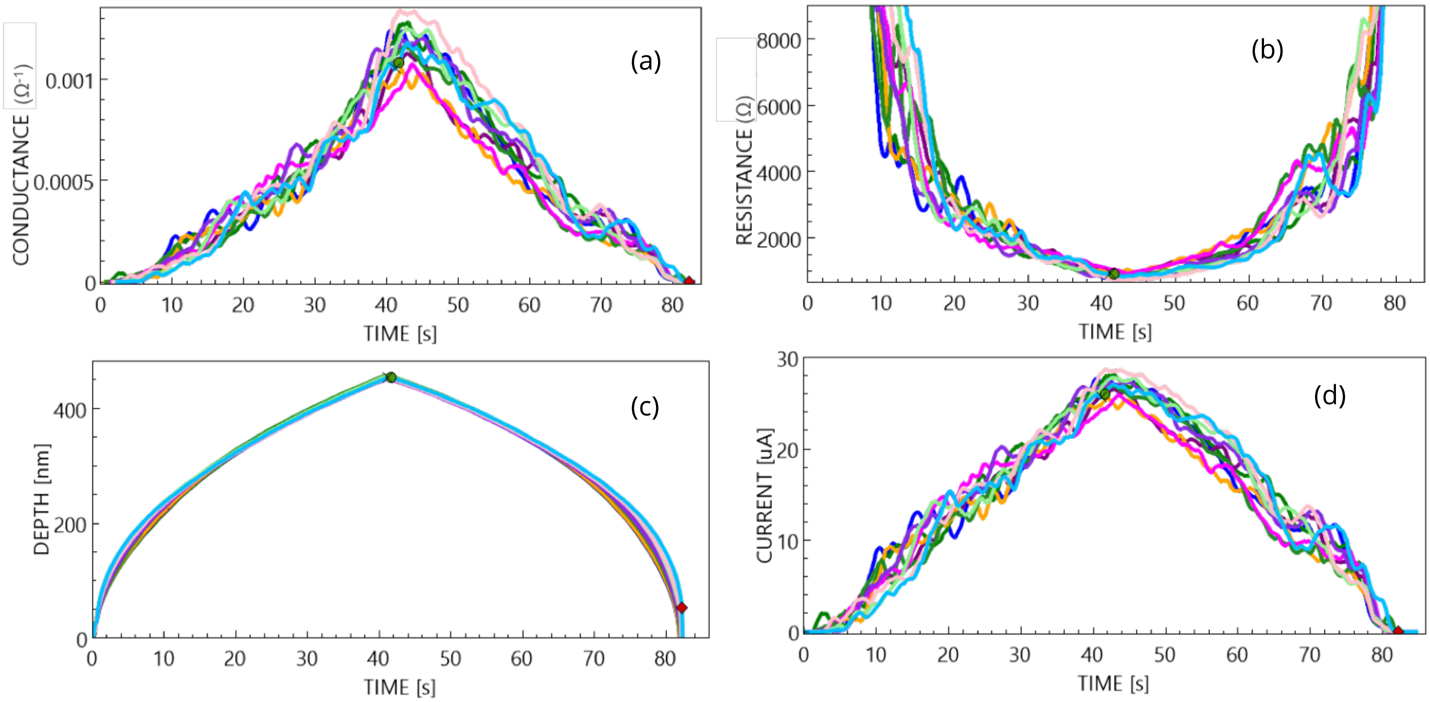


Figure 4. Simultaneous measurement of conductance, resistance, indentation depth and resulting current as a function of time for the pyrolytic carbon sample. Results shown are for a series of ten repeated tests.

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