CURRENT-INDUCED NANOGAP FORMATION AND GRAPHITIZATION IN BORON-DOPED DIAMOND FILMS


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1. Introducción

A high-current annealing technique is used to fabricate nanogaps and hybrid diamond/graphite structures in boron-doped nanocrystalline diamond films [1]. Nanometer-sized gaps down to ~1 nm are produced using a feedback-controlled current annealing procedure. The nanogaps are characterized using scanning electron microscopy and electronic transport measurements. The structural changes produced by the elevated temperature, achieved by Joule heating during current annealing, are characterized using Raman spectroscopy. The formation of hybridized diamond/graphite structure is observed at the point of maximum heat accumulation.

2. Experimental

B:NCD films were grown on a silicon oxide substrate in an ASTeX 6500 series using microwave plasma-enhanced CVD technique. B:NCD-based devices were fabricated from the film by using standard electron beam lithography. After fabrication, the devices were characterized employing optical microscopy, atomic force microscopy (AFM), electrical transport measurements at low temperature, scanning electron microscopy (SEM) and Raman spectroscopy.

FIG. 1. (a) Optical image using a 100× magnifying objective marked with AFM scan area (dashed square) and (b) corresponding SEM image of the device fabricated on the B:NCD film. (c) Topography AFM image of the device with height profile (red curve). (d) Current vs. voltage characteristics of the device measured at 5.4 K (red curve) and 54 mK (blue curve).
3. Resultados y discusión

B:NCD devices were then subjected to high-current annealing in air at room temperature using a feedback-controlled scheme, as shown in Fig. 2(a). A voltage (V) ramp with a rate of 1 V/s was applied to the device while the current (I) was measured every 100 µs. If the conductance (I/V) drops >10% within a 200 mV range, the voltage was swept back to zero after which a new ramp was started. This process was repeated until a gap was formed (Fig. 2(b)). Figure 2(c) shows a typical I-V graph of the feedback-controlled high-current annealing process. The current increases with the voltage until a critical point where the conductance starts to decrease (indicated by the red circles in Fig. 2(c) for easy detection). The arrow in Fig. 2(c) indicates the evolution of the I-V traces after sequential high-current annealing steps, eventually leading to a nanogap. The nanogaps in the first batch of B:NCD devices were found to be around 100 nm and approximately in the middle part between the two leads.

After the high-current annealing, on the other hand, the Raman spectrum measured close to the nanogap changes drastically (Fig. 3(a)). The spatial distribution of the structural changes induced by high-current annealing has been studied by performing scanning Raman spectroscopy. The structural changes produced by the current-induced heating have been studied by Raman spectroscopy. We found that Joule heating increases the temperature enough to change the hybridization of diamond, dominated by sp³, to a graphitic sp² hybridized.

4. Bibliografía