ARRAYS OF NOVEL SINGLE CRYSTAL DIAMOND CONES

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The unique geometrical configurations of many materials, for example, with conical structures may provide the properties which can be observed in neither their bulk nor film forms. Dense conical arrays have been suggested in many devices such as controlled thermonuclear fusion devices for the construction of their inner walls, absorbers in solar cells, and cold cathodes in field emission devices. Such applications, however, require materials with exceptional properties enduring the harsh operation conditions. Diamond is an exceptional material, which combines its outstanding physical and chemical properties. Among them the highest hardness and Young's modulus, highest thermal conductivity, outstanding chemical inertness, semiconducting wide band gap property, and negative electron affinity (NEA) profit its use in both mechanical and electronic applications. The intrinsic properties of diamond in combination with the distinctive surface morphology of cone structures will emerge some non-fungible applications. Indeed, diamond in tip formats has been developed and showed advantages in practical applications. For example, sharp silicon probes used in scanning probe microscopes (SPM) have been coated with thin polycrystalline diamond films. For the same purpose, very fine polycrystalline diamond pyramids have also been made by a so-called moulding technique. It was also demonstrated that coating silicon tips by CVD diamond could dramatically improve the entire emission parameters.

We have developed a new method to fabricate uniform arrays of diamond nanocones characteristic with very high aspect ratio over large areas. The fabrication process of diamond nanocones is based on two fundamental steps: i) deposition of diamond films which serve as input materials for ii) subsequent bias-assisted reactive ion etching for the construction of the arrays of diamond nanocones. The crystallographic configuration of the diamond films synthesized in step i) plays a decisive role for the formation and crystalline nature of the diamond nanocones fabricated in step ii). On the [001]–oriented diamond films, arrays of very sharp diamond cones with an apical angle of 28^o and a tip radius as small as 5 nm have been fabricated. Each cone was identified to be a diamond single crystal with its [001] axis perpendicular to the substrate surface (see Figure 1). Alternatively, when nanodiamond films were used as input materials for reactive ion etching as described in step ii), array of cones composed of nanocrystalline diamond particles was formed, which shows improved field emission properties particularly in reducing the turn-on electric field. The mechanism of the cone formations has been understood in terms of the plasma sheath and space charge formation just above the diamond structure, and seems to be applicable for manufacturing conical structures being based on a wide range of materials including silicon carbides and nitrides.

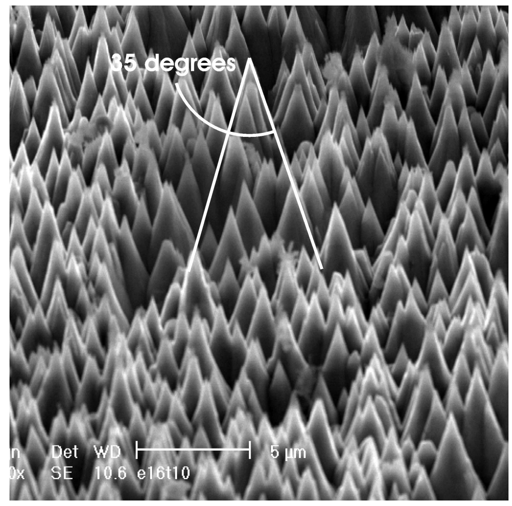

FIG.1 SEM image collected from a sample tilted in an angle of 45^o towards the SEM detector and showing that nearly all diamond cones are uniform in both tip size and aspect ratio.