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Synthesis of Tetrahedral Amorphous Carbon by Mixed Mode HiPIMS Deposition

Nigel Marks[1], Rajesh Ganesan[2], Mark Tucker[1], Dougal McCulloch[3], James Partridge[3], Michael Stueber[4], Sven Ulrich[4], Marcela Bilek[2], David McKenzie[2]

[1]Curtin University, Perth, Australia [2]University of Sydney, Sydney, Australia [3]RMIT University, Melbourne, Australia [4]Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

N.Marks@curtin.edu.au

Tetrahedral amorphous carbon (ta-C) is a technologically important form of carbon containing a high fraction of sp^3 bonded atoms. Conventional approaches based on DC sputtering or High Power Impulse Magnetron Sputtering (HiPIMS) have struggled to produce ta-C due to insufficient ionization, and so ta-C is typically produced commercially using cathodic arc deposition. Here, we show that operating HiPIMS in a mixed mode, in which controlled arcs ignite on the surface of the cathode, produces a sufficiently high ionization fraction to enable deposition of ta-C.
Films were deposited onto silicon substrates using a substrate bias between 0 and –500V, pulse lengths between 90 and 210 us and Ar pressures between 1.75 and 4 mTorr. Optimal conditions for ta-C production involved long pulse lengths, pressures no greater than 2.25 mTorr and a bias of –100V. Varying the substrate bias reproduced the well-known energy window effect in which the sp^3 fraction is substantially reduced for high and low biases, thus demonstrating that the deposition flux is highly ionized.
The sp^3 fraction was determined using XPS and confirmed independently using EELS measurements. Ellipsometry showed that the Tauc optical gap is as high as 2.7 eV for the ta-C films and 1.7 eV for the films with low sp^3 content. Other key signatures of ta-C were all present, including high compressive stress, a symmetric Raman peak, a high water contact angle and very low surface roughness as measured by AFM. Nanoindentation measurements yielded a reduced modulus of 345 GPa, very similar to that of ta-C deposited by filtered cathodic arc, and elastic recoil detection analysis showed the hydrogen content was very low, at around 0.3 at. %.

Keywords
HiPIMS
tetrahedral amorphous carbon
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