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**PLASMA, PHOTON, AND BEAM SYNTHESIS OF DIAMOND FILMS
AND MULTILAYERED STRUCTURES**

Progress Report

for period July 1, 1990 - June 30, 1991

R.P.H. Chang

Materials Science & Engineering Dept.
Northwestern University
Evanston, IL 60208

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Abstract

Three major areas of fundamental research on diamond thin films have been explored during the last period, 1990 - 1991. A new microwave plasma enhanced laser ablation system has been designed and constructed. This system is currently being used to study the possibility of depositing diamond films on plastic surfaces. A mechanism for nucleating diamond films on single crystal copper surfaces has been proposed and detailed experiments have been carried out. Carbon clusters of C_{70} have been successfully used to nucleate diamond on non-diamond surfaces. This invention provides an alternative to using diamond - grit polish as a nucleating agent.

Introduction

The diamond research program has been successfully carried out during the period 1990 - 1991 at Northwestern under the sponsorship of the Department of Energy. Our research focus has been on: diamond nucleation and growth on non-carbide forming metal surface; designing and constructing a new system for diamond film deposition on plastic surfaces; and finding suitable diamond nucleating agents to replace diamond-grit polish. Significant accomplishments from the past 12 months are discussed below:

1. Diamond Nucleation and Growth on Copper Surfaces

The nucleation and growth of diamond crystals on single crystal copper surfaces has been studied. Microwave plasma enhanced CVD was used for diamond deposition. The single crystal Cu substrate was implanted at elevated temperature ($\sim 820^\circ\text{C}$) with carbon ions prior to diamond deposition. This procedure leads to the formation of a graphite film on the Cu surface which greatly enhances the diamond crystallite nucleation. From our study we construct a simple lattice model for diamond growth on graphite as $\langle 111 \rangle$ diamond parallel to $\langle 0001 \rangle$ graphite and $\langle 110 \rangle$ diamond parallel to $\langle 1120 \rangle$ graphite.

2. Design and Construction of A New Diamond Deposition System

Funding support received from the state of Illinois allowed us to design and construct a new microwave plasma assisted laser ablation system for the purpose of studying diamond deposition on plastic surfaces sponsored under DOE grant. The system is already in operation and preliminary data taken seem to be promising. The system will be in full operation by the end of the year.

3. Nucleation of Diamond Films on Surfaces Using Carbon Clusters

A unique method for nucleating diamond films on surfaces using C clusters is described. The process substitutes the need for diamond polish pretreatment of substrates prior to diamond film growth, as currently practiced in low-pressure (<1 atm) chemical vapor deposition methods. We have used C₇₀ films as diamond nucleating layers on single-crystal Si, SiO₂, and Mo surfaces. It is shown that a thin layer (approximately 1000 Å) of pure carbon C₇₀ is sufficient for the nucleation and growth of fine grain polycrystalline diamond films. The enhancement of nucleation by the C₇₀ layer is nearly ten orders of magnitude over untreated surfaces. It also follows that C clusters can be used as a one-step lithographic template for growing diamond on selected regions of the substrate. In addition, insight into the mechanism for diamond nucleation from C clusters has been obtained.

Other Federal Funding:

Agency: Department of the Navy, Office of Naval Research (ONR)
Amount: \$ 125,752
Title of Research: Surface Nucleation & Growth of Diamond Films for Optical & Wear Applications
Period of funding: 10/1/90 - 9/30/91

Due to unexpected DOE budget cuts, part of the ONR funding was used to sustain the on-going DOE research.

Status of Students

Raymond J. Meilunas, Ph.D. Candidate
He graduated in October 1991 and is currently employed by Grumman Aerospace Co.

Tiong P. Ong, Ph.D. Candidate
He graduated in November 1991 and is currently employed by Jet Propulsion Laboratory.

Kevin Grannen, Ph.D. Candidate
Expected graduation date: November 1993

Fulin Xiong, Postdoctoral Associate
Half time on this project

Publications/Presentations Supported by This Grant:

A. Papers and Proceedings:

"Infrared and Raman Spectra of C_{60} and C_{70} Solid Films at Room Temperature", R. Meilunas, S. Liu, R.P.H. Chang, M. Kappes, J. Appl. Phys. **70**, 5128 (1991)

"Nucleation of Diamond Films on Surfaces Using Carbon Clusters", R. Meilunas, R.P.H. Chang, S.Z. Liu, M. Kappes, Appl. Phys. Lett., **59** (1991)

"Activated C_{70} and Diamond", R. Meilunas, R.P.H. Chang, S.Z. Liu, M. Kappes, Nature, **354**, 271 (1991)

"A Mechanism for Diamond Nucleation and Growth on Single Crystal Copper Surfaces", T.P. Ong, F.L. Xiong, R.P.H. Chang, submitted to Appl. Phys. Lett., (1991)

B. Oral Presentations:

"Overview of Diamond Film Technology: Trends and Opportunities", R.P.H. Chang, National Center for Manufacturing Science Day (Nov. 20), Northwestern University, Nov. 1990

ibid, R.P.H. Chang, Chicago-Milwaukee Section of American Ceramic Society, March 1991

"Preparation, Characterization and Application of Buckminsterfullerene", S. Liu, J. Hunter, V. Dravid, R. Meilunas, R.P.H. Chang, Manfred Kappes, Industrial Associates Meeting, Northwestern University, March 1991

ibid, S. Liu, R.J. Meilunas, V.P. Dravid, R.P.H. Chang, M. Kappes, The International Workshop on Science and Technology of Thin Diamond Films for the 21st Century, Northwestern University, Evanston, IL, July 1991

"A Mechanism for Diamond Nucleation and Growth on Single Crystal Copper", T.P. Ong, R.P.H. Chang, C.W. White, The International Workshop on Science and Technology of Thin Diamond Films for the 21st Century, Northwestern University, Evanston, IL, July 1991

"Diamond Film: Science and Technology", R.P.H. Chang, Technology Reviews Seminar, Northwestern University, Evanston, IL, Nov. 1991

"Fullerene Thin Films: Raman, IR Absorption, STM and HRTEM Characterization, Application in Diamond Nucleation", R.J. Meilunas, Shengzhong Liu, V. P. Dravid, R.P.H. Chang, M. Kappes, Materials Research Society Fall Meeting, Boston, MA, Dec. 1991

"Nucleation of Diamond Films on Surfaces Using Carbon Clusters",
R. Meilunas, R.P.H. Chang, S.Z. Liu, M. Kappes, Materials
Research Society Fall Meeting, Boston, MA, Dec. 1991

"Diamond Nucleation Using Carbon Clusters", R.P.H. Chang, Japan
Materials Research Society Meeting, Tokyo, Japan, Dec. 1991

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