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研究課題名（英文）Opt-electrical properties of nanodiamond films and their application to photovoltaics

研究代表者

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研究成果の概要（和文）：超ナノ微結晶ダイヤモンド膜による金属-半導体-金属（MSM）構造，Siとのヘテロpn接合，およびホモpn接合素子を作製した．ホウ素ドープUNCD膜のMSM構造は銅電極によるコンタクトが最も高い接触抵抗を示し，暗電流の抑制により，光導電型で受光特性の評価が可能であることを実証した．また，電流スペクトルにおける紫外光と可視光域の光応答をそれぞれがUNCD結晶粒と結晶粒界に起因する可能性が高いことがわかった．p型膜と金属コンタクト間におけるショットキー障壁高さを，紫外光電子分光法とX線光電子分光法により見積もり，ショットキーとオーミックコンタクトの形成が自在に作製可能であることを示した．

研究成果の概要（英文）：Metal-semiconductor-metal (MSM) structures, hetero pn junctions, and homo pn junctions comprising ultrananocrystalline diamond films were prepared. For the MSM structures, it was found that Cu electrodes can suppress the dark current and its employment makes possible clear photodetection in the MSM structure, and their photo-responses in the ultraviolet and visible range might be attributed to photo-carriers generated in nanodiamond grains and grain boundaries. In addition, the Schottky barrier height was estimated from ultraviolet and X-ray photoemission spectra measured with synchrotron radiation, and it was proved that Schottky/ohmic contacts are flexibly formed by selecting metallic materials.

研究分野：薄膜工学

キーワード：カーボン薄膜　ナノダイヤモンド　物理気相成長法　光電変換　同軸型アークプラズマ堆積法　半導体pn接合　少数キャリアのライフタイム

１. 研究開始当初の背景
この提案では, カーボン系新材料の超ナノ微結晶ダイヤモンド(UNCD)/水素化アモルファスカーボン(a-C:H)混相膜に注目する. この後は略して UNCD 膜と呼ぶことにする. UNCD 膜は粒径 10 nm 以下のダイヤモンド微結晶が a-C:H マトリックス中に無数に存在する構造を持つ. この膜は膜中に多数の UNCD 結晶の界面（以後 粒界と呼ぶ）が存在するため, それを原因とすると考えられる特異な物性が発現する. 例えば, 極めて大きな光吸収や結晶ダイヤモンドでは不可能な N ドープによる n 型化などである. UNCD 膜の作製は CVD 法によって研究されてきた. それに対して, 我々は物理気相成長法であるﾚｰｻﾞｰｱﾌﾞﾚｰｼｮﾝ（PLD）法および同軸型アークプラズマガン蒸着（CAPD）法で, その成長を世界で初めて実現した. これらの方法では次のような大きな特徴がある：(1) 基板へのシーディング処理が不要, (2) 異種基板への成長が容易, (3) 膜表面が非常に平滑, (4) 高速堆積が可能, 等である.　生成する膜の性質も異なる. CVD 法では 10 nm 以下に粒径を小さくすることが難しいのに対して, 我々の方法では容易である. 我々の報告した極めて大きな光吸収係数は, 粒径が小さいことによる無数の粒界が含まれることにより発現していると考えている.

２. 研究の目的
UNCD 膜は, 内在するダイヤモンド結晶に起因する紫外域の光電流と, 可視域で粒界に起因すると考えられる独特の強い光吸収と光電流を示す. これらの光受光特性をそれぞれ UV 受光素子および太陽電池に応用することを目指す. 特に, 太陽電池への応用に重点を置き, UNCD 膜のみをコアとするホモ pn 接合太陽電池の創製を目指す.

３. 研究の方法
膜作製は保有する PLD および CAPD 成膜装置で行う. 生成膜の構造評価は, 学内共同利用施設で FTIR 測定を行うほか, SAGA-LS にて XRD, NEXAFS, PES 測定, 微細構造観察を九州大学超高圧電子顕微鏡室で行う. 光・電子物性測定も研究室の保有する装置でほとんど行えるが, フォトキャリアのライフタイム測定を宮崎大学で, 膜中不対電子を調べるための ESR 測定を九工大にて行う.

４. 研究成果
UNCD/a-C:H 膜を用いた金属-半導体-金属（MSM）構造, Si とのヘテロ pn 接合およびホモ pn 接合の作製, 受光デバイスの試作とそれらの光電変換特性の評価, さらには, 少数キャリア寿命測定と放射光を用いた光電子分光法による金属コンタクトにおける界面状態の詳細な解析により, 以下の示す光電変換素子の創製に向けた多くの知見を得た：i) ホウ素ドープ UNCD/a-C:H 膜の光導電特性を MSM 構造により調査した. 銅電極によるコンタクトが最も高い接触抵抗を示し, 暗電流の抑制により, 光導電型で受光特性の評価が可能であることを実証した. 電流スペクトルが紫外光と可視光の波長領域で明確な光応答を示し, それぞれが UNCD 結晶粒と結晶粒界に起因する可能性が高い; ii)p 型 UNCD/a-C:H 膜と n 型 Si 基板により構成されたヘテロ pn 接合ダイオードを, 深紫外線フォトダイオードとして評価した. 低温下で受光能に大幅な改善がみられなかった. その一因として, 伝導帯におけるバンドオフセットに起因するヘテロ接合界面に現れるスパイクが, 低温環境下においては顕在化し, UNCD/a-C:H 層から Si 層へのフォトキャリアの輸送を妨げていると考察している; iii)マイクロ波光導電減衰法により少数キャリア寿命を調べ, 水素化により少数キャリア寿命が明確に増加することを明らかにした. トラップセンターとして作用する未結合手が原子状水素によって終端された可能性が高い；iv)p 型 UNCD/a-C:H 膜と金属コンタクト間におけるショットキー障壁高さを, シンクロトロン光を用いた紫外光電子分光法と X 線光電子分光法により見積っている. 仕事関数の値を考慮して電極金属を選定することで, ショットキーとオーミックコンタクトの形成が自在に作製可能である.

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〔図書〕（計 0 件）

〔産業財産権〕
○出願状況（計 0 件）
○取得状況（計 0 件）

〔その他〕
ホームページ等
http://yoshitake.private.coocan.jp/univ_lab/index-j.htm

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