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「画素の小さいX線検出用CCDの開発」

1. 研究実施の概要

X線はその波長が短いために、光電吸収が起こると一つのX線光子が一度に多数の一次電子を発生し、その電子数はX線のエネルギー(波長)に比例する。これを精密に測定することを目指す。こうして、CCDによりX線検出を行うと、X線の強度とそのカラー(波長)、更にその入射位置や直線偏光度なども同時に測定できる。そこで、可視光検出に使われるCCD素子と比較してはるかに厚い空乏層を持ち、小さな画素で入射位置の測定精度を向上すると共に、低雑音化を計り、偏光測定やエネルギー測定の精度を高める。これにより、効率の良いカラーX線撮像装置を目指す。また、宇宙環境を念頭に置き、高い放射線レベルによる損傷が起こった場合に、適切に対応できるようにする。

X線検出用にデザインされたCCDで、小さな画素を持ち、X線偏光検出能力を持った素子を開発研究するため、従来の素子を次第に改良した。フレーム転送型の素子で、撮像有効面が25mm四角、三面バタプル(隙間なく埋めることができる)の素子を製作した。X線検出効率改善のため、シリコンウェハーで比抵抗の大きいものを使い、50 μ m程度と可視光用に比べて一桁厚い空乏層を実現した。素子搭載アンプの低雑音化を計り、冷却と組み合わせ、周辺回路を含めた雑音レベルとして電子個数換算で3~4個を実現した。6keVのX線に対するエネルギー分解能は半値幅で135eVである。次に、実験室での直線偏光単色ビームを作った。これにより、CCDによる偏光度測定性能や手法を開発した。また、メッシュ実験を考案し、CCD素子内部で、どのような形状の電荷雲が作られているかを実測した。この手法はアメリカやヨーロッパの衛星搭載素子の測定にも使用された。CCD素子の空乏層、中性領域で作られた電荷雲の振るまいを調べた。これを基にイベント解析により高エネルギー側の検出効率を向上させる方法を開発した。小さな画素を目指して、12 μ m四角、8 μ m四角を開発、さらに小さな画素を持つ素子を試作したが、小さな画素になると、飽和電荷量の低減、電荷転送効率などに問題が生じた。しかし、電荷形状を利用した入射位置決定精度を向上する技術を開発し、入射位置精度としてサブ μ mを達成できるようになった。次に、高い放射線環境における使用を念頭において、放射線損傷を受けたCCDの性質を調べ、その性能回復方法を開発した。更に、1MeV程度の電子の作るトラックを詳細に調べ、空乏層厚みと高エネルギーX線の検出効率を測定する新しい方法の開発した。

本研究を進める上では、チームメンバー各員の働きはもちろんであるが、関連の皆様のご協力も研究遂行には不可欠であった。中でも科学技術振興事業団のつくば事務所の皆様、大阪大学や京都大学の事務方には、研究を支障なく遂行する上で大変お世話になった。ここに厚くお礼申し上げる次第である。

2 . 主な研究成果

(1)論文発表 (国内 50件、海外 144件)

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(2)口頭発表

招待、口頭講演 (国内 30件、海外 18件)
ポスター発表 (国内 40件、海外 20件)
プレス発表

(3)特許出願 (国内 2件、海外 1件)

国内
常深博 画素よりも細かい分解能でCCDのX線検出効率を測定する方法およびその装置
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海外

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(4) その他特記事項

現在、開発したX線用の素子を使って汎用のCCDカメラを製作しようとしている。これにより我々の作成したX線用CCDを広く一般に使用できるようにしたい。また、この開発を通じて培った技術を使って、国際宇宙ステーションに搭載する予定の全天X線監視装置に、32個のCCD素子を並べたCCDカメラ(SSC)を製作している。