# 行政院原子能委員會
# 委託研究計畫研究報告

## 複合電漿改質製程技術應用於提昇模具壽命之機械性質研究

計畫編號：952001 INER018

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報告日期：2006 12 30

# 中文摘要

本研究報告為探討 420 與 SKH51 兩種模具鋼材經過不同氮氫流量比的電漿浸末離子注入(PIII)氮化法處理與鍍製類鑽石薄膜(DLC)後，DLC 薄膜與氮化層之間的附著力與機械性質的變化。PIII 氮化條件為固定注入電壓 12kV、腔體氣壓 4.5 mTorr 與氮化溫度 500℃，改變不同氮氫流量比，分別為 45：0 sccm、 28：28 sccm 以及 12：36 sccm 等三種條件，DLC 鍍膜時間分別為 30 與 150 分鐘，兩種條件的估算膜厚分別為 460 nm 與 1600 nm。在量測方面，利用奈米試驗機(MTS、Nanotest)進行 DLC 薄膜之機械性質(硬度、楊式模數、薄膜抗磨耗特性)之量測，利用輝光放電分光儀(Global discharge spectrometer, GDS)與 X 光繞射分析儀(X-ray diffraction spectrometer, XRD)量測改質層厚度並分析其結構狀態，最後利用拉曼光譜儀(Raman spectrometer)分析 DLC 之鍵結組成。

研究結果顯示 420 與 SKH51 兩種鋼材在進行 PIII 氮離子植入之後，其表面硬度與楊氏模數皆能有大幅度地強化。PIII 類鑽碳膜沉積後表面硬度與楊氏模數雖然沒有單純 PIII 氮改質層來得高，但仍舊比基材高上 2 到 6 倍不等。沉積時間愈久，即膜厚愈厚的類鑽碳膜，其石墨化指數較高，進而使其硬度與楊氏模數比薄的類鑽碳膜要低一些，但是厚膜比薄膜有較高的臨界負

載與抗磨損性能。經由奈米刮痕實驗無法明顯看出氮化改質層對於 DLC 薄膜附著力的影響，但是沒有經過氮化處理的試片在鍍膜後不久即產生部份剝落的現象，顯示氮改質層有助於增加 DLC 薄膜與鋼材間的附著力。

# 英文摘要

The adhesion force between diamond like carbon (DLC) thin film and nitriding layer at 420 and SKH51 steels are discussed in the report. The nitriding layer is formed by plasma immersion ion implantation (PIII) nitriding treatment at different flow ratio of nitrogen and hydrogen conditions. Fixed conditions of PIII nitriding treatment are bias (12 kV), gas pressure (4.5 mTorr) and nitriding temperature (500℃). Flow ratios of nitrogen and hydrogen are varied at three conditions, and they are 45：0, 28：28 and 12：36 sccm. The DLC coating are treated by PECVD on nitriding and non nitriding steels with 30 mins and 150 mins, so the thickness of DLC films are 460 nm and 1600 nm, respectively. Nano indenters (MTS and Nanotest) are used to measuring mechanical properties of DLC film, which including hardness, Young's modules and anti-wear performance. Thickness and components of Nitriding layer are measured by using Global discharge spectrometer (GDS) and X-ray diffraction spectrometer (XRD). Finally, the Raman spectrometer is used to analyzing binding and component.

From analyzing results, surface hardness and Young's modulus of nitriding steels of 420 and SKH51 increased highly after PIII nitriding treatment. The hardness and Young's modulus of DLC film are lower than nitriding layer, but also higher than untreated steel two to six order. Because thicker DLC film contained more weight carbon in it. So hardness and Young's modulus of thicker DLC film (1600 nm) were lower than thinner DLC film (460 nm), but critical load and anti-wear performance were higher than thinner one. By nano scratch

test can not significantly find the influence of adhesion force between nitriding layer and DLC film. But comparing nitriding and untreated specimens can find that DLC film already pitted from untreated one. The phenomena shows DLC film can bind well at nitriding layer.