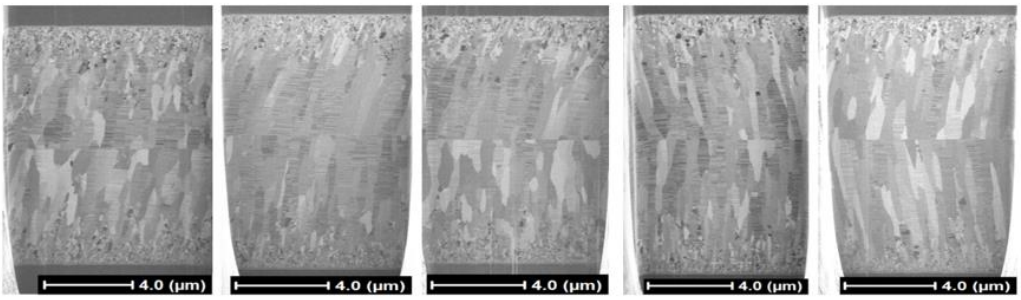
濺鍍及蒸鍍銀奈米孿晶薄膜及其在 3D-IC 與功率 IC 產品的應用

奈米孿晶薄膜具有(111)優選方位，其擴散係數較(100)及(110)晶面高 2 到 5 個數量級，應用在 3D-IC 前段「系統整合晶片(SoIC)」堆疊元件與後段「晶片對晶圓對基板(CoWoS)」先進封裝的「晶圓接合」，以及功率 IC 模組的「固晶接合」，均可以有效降低製程溫度；Si 晶圓電鍍 Cu 奈米孿晶及其低溫直接晶圓接合過去已有文獻報導，本實驗室進一步在 Si、Ge、GaAs、SiC 及 Sapphire 晶圓成功濺鍍出 Ag 奈米孿晶薄膜，XRD 及 EBSD 分析具有 98%以上的(111)-結晶方位及 64%以上的 CSL-Σ3 孿晶界比例，HRTEM 影像顯示 Ag (111)孿晶原子間隔僅 0.24 nm，孿晶界間距約 2 至 50nm；基於蒸鍍製程較濺鍍更具有高生產效率與低成本優勢，亦與新竹科學園區樂鑫材料科技公司(Amtc)合作開發一種創新的離子撞擊輔助蒸鍍技術，在全世界首度以蒸鍍製程生產高密度(111)銀奈米孿晶薄膜於各種半導體晶圓。我們的銀奈米孿晶應用性也經由 100℃低溫達成矽晶/矽晶的直接晶圓接合及矽晶/DBC 陶瓷基板的固晶接合得到驗證。習知電鍍銅奈米孿晶必須高速攪拌，製程及薄膜品質不易控制，且有環保顧慮，銀在所有元素中具有最低疊差能，易形成孿晶結構，銀的擴散速率是銅的 10 倍，有利於低溫接合，銀的導電及導熱性也優於銅，且較不易氧化，銀的硬度較低，可減少接合界面孔洞，這些優點確保我們的濺鍍與蒸鍍銀奈米孿晶低溫晶圓接合與固晶接合技術在半導體產業的競爭優勢。(莊東漢教授提供)

台大銀奈米孿晶低溫晶圓接合



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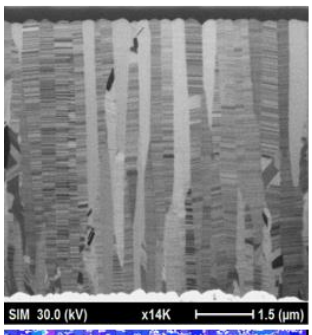
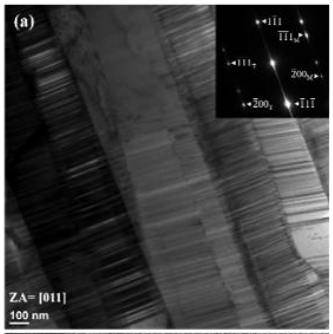
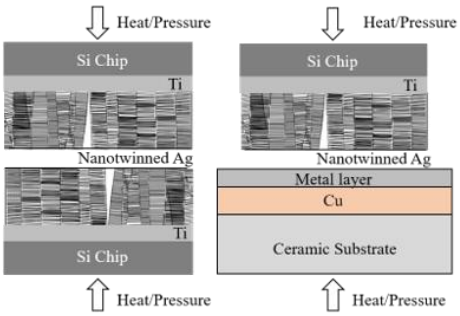
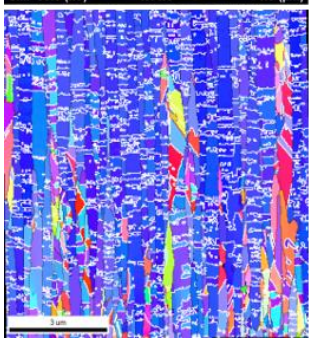
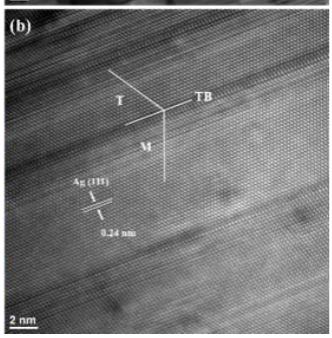
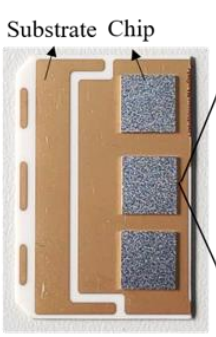


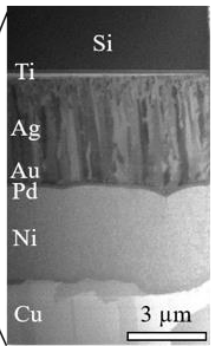








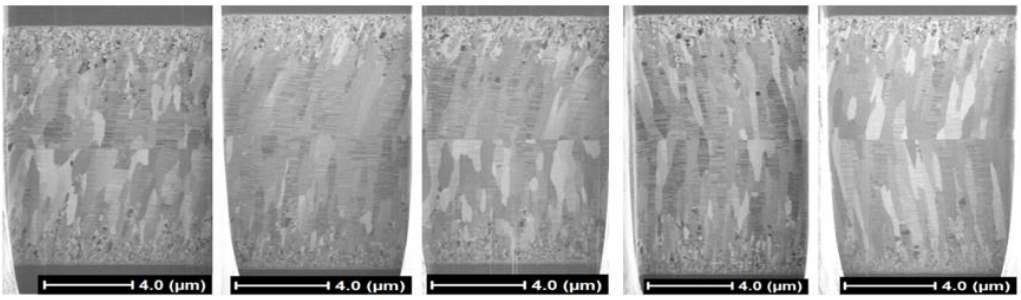




Sputtering and Evaporating Ag Nanotwinned Films and their Applications in 3D−IC and Power IC Products

Ag nanotwinned films have a (111) preferred orientation and diffusivity that is 2 to 5 orders of magnitude higher than those of (100) and (110) surfaces. For applications in “wafer bonding” of 3D-IC front-end “Systems on Integrated Chips (SoIC)” stacking devices and back-end “Chip on Wafer on Substrate (CoWoS)” advanced packages, and in “die attachment” of power IC modules, the processing temperature can be effective reduced. Electroplating Cu nanotwinned film on Si wafer and its low temperature direct wafer bonding have been reported previously in literature. Our laboratory further successfully sputtered Ag nanotwinned films on Si, Ge, GaAs, SiC and sapphire wafers. XRD and EBSD analyses evidenced more than 98% (111)-orientation and 64% CSL-$\sum 3$ twin boundaries. The Ag (111) nanotwins have atomic spacing of about 0.24 nm and twin boundary pitch of 2 to 50 nm, as shown in HR-TEM micrographs. Due to the high production efficiency and low cost of the evaporating process in comparison with those of sputtering, we also cooperated with Ag Materials Technology Co. (Amtc) at the Hsinchu Science Park to develop an innovative evaporating method assisted by ion beam bombardment. With this method, we produced high density Ag nanotwinned films on various semiconductor chips using evaporating process for the first time ever. The applicability of our Ag nanotwinned films has also been verified by the satisfactory direct wafer bonding between Si/Si and die attachment between Si/DBC ceramic substrate at 100 ℃. Unlike the conventional electroplating process, our sputtering and evaporating methods require no high speed stirring, is easy to control, and produces high quality thin films without raising environmental concerns. Ag has the lowest stacking fault energy of all the elements and easily forms twin structures. The diffusivity of Ag is 10 folds higher than that of Cu, which is beneficial for low temperature bonding. The oxidation resistance and the electrical and thermal conductivity of Ag are also superior to those of Cu, and the hardness is lower, leading to fewer voids at the bonding interface. These advantages ensure the competitive supremacy of our low temperature wafer bonding and die attachment techniques with sputtering and evaporating Ag nanotwinned films in the semiconductor industry. (Provided by Prof. Tung-Han Chuang)

台大銀奈米孿晶低溫晶圓接合



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