THE ROLE OF INTERFACE STRESS IN THE THERMAL DEGRADATION OF CU/W NANO-MULTILAYERS

Druzhinin A. V.[1]*, Cancellieri C.[2], Straumal B. B.[1,3,4]

[1]National University of Science and Technology «MISIS», Moscow, Russian Federation
[2]Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf, Switzerland
[3]Institute of Solid State Physics and Chernogolovka Scientific Center, Russian Academy of Sciences, Chernogolovka, Russian Federation
[4]Karlsruhe Institute of Technology (KIT), Eggenstein-Leopoldshafen, Germany

INTRODUCTION

Nano-multilayers are functional nano-architectures, which mechanical, chemical and physical properties can be tailored by smart microstructural and interfacial design. Upon thermal treatment, the layered structure of NMLs of immiscible metals degrades, forming the nanocomposite microstructure. The mechanical, electrical and thermal properties of NCs can be tailored by varying the formed microstructure through the change of initial thicknesses of constituent nanolayers in NMLs. The driving force of the degradation is of capillary nature, i.e. the system tends to decrease the energies of interfaces by wetting.

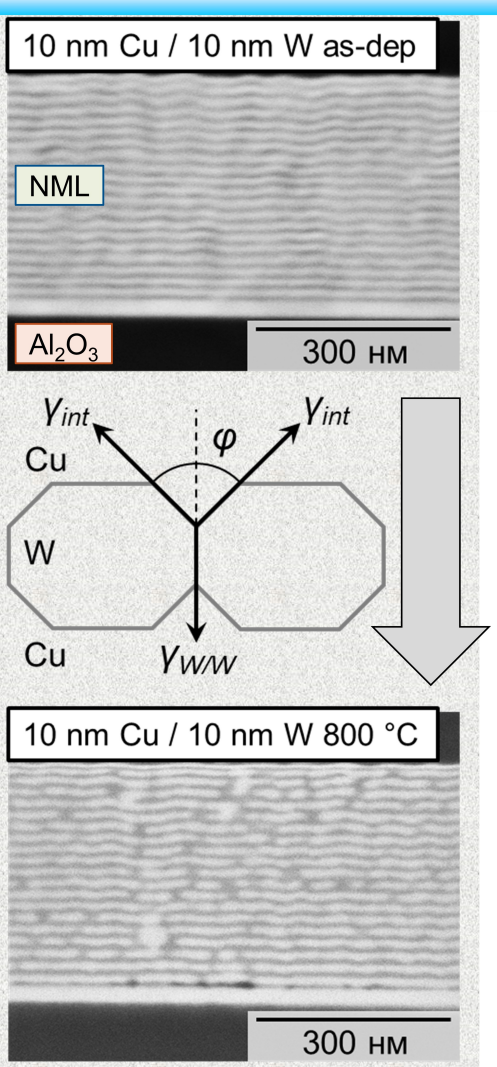
In the present work, the degradation upon thermal annealing (400 – 800 °C; duration of 100 min; 5×10^{-3} mbar pressures) of sputtered Cu/W NMLs with different nanolayer thicknesses (3, 5, 10 nm) is rationalized. Substrate: Al_2O_3 (0001) + 25 nm W buffer. The amount of Cu/W bilayer repetition is constant and equal to 20.

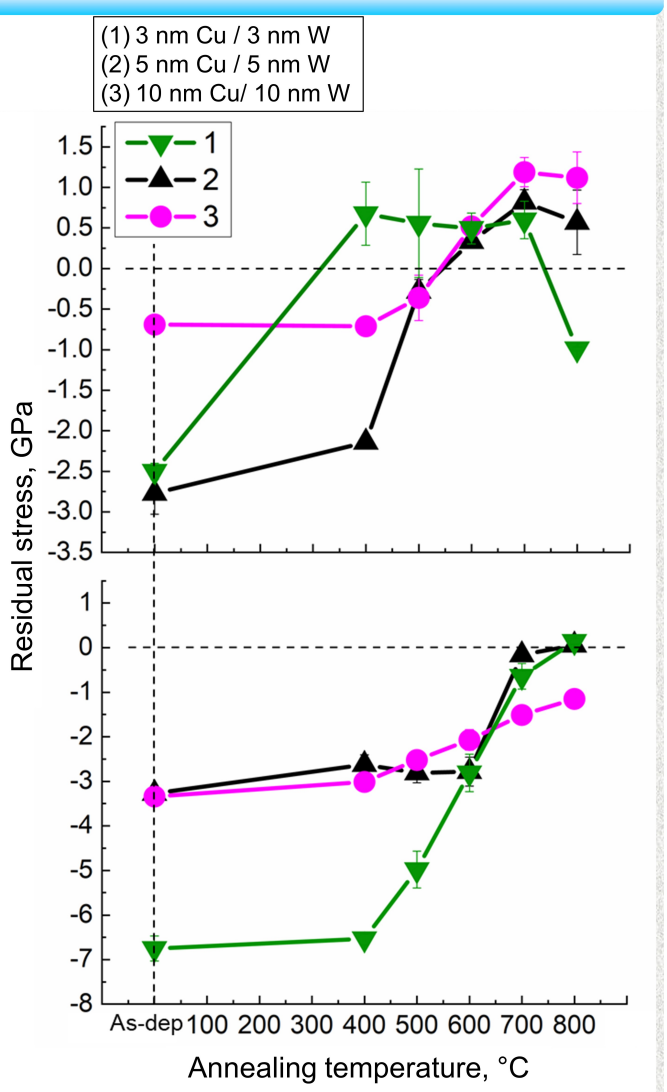
RESULTS

Upon the increase of annealing temperature NML begins to degrade. The degradation is governed by the wetting of W/W grain boundaries by Cu phase, which is defined by the conventional Young equation:

$$\cos\left(\varphi/2\right) = \frac{\gamma_{W/W}}{2\gamma_{int}}$$

ϕ is the wetting angle;
$\gamma_{W/W}$ is the W/W grain boundary energy
$\gamma_{Cu/W}$ is the Cu/W interface energy

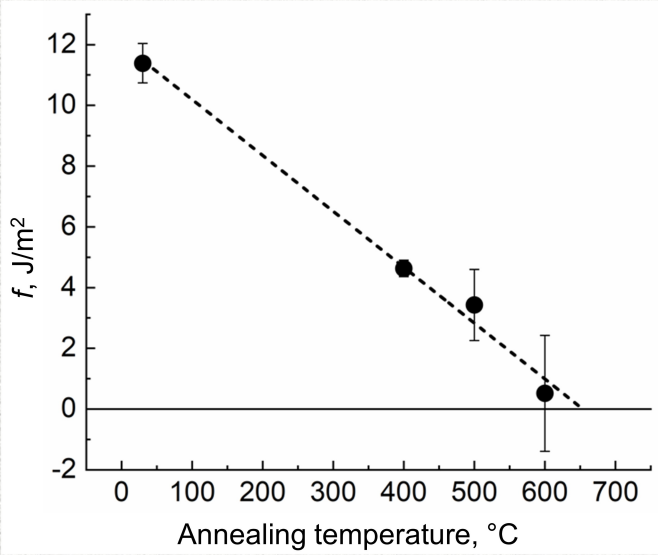




However, the degradation begins only after annealing in the range of 700-800 °C, despite the Cu/W interface energy is lower than energies of possible W/W grain boundaries already at absolute zero. This phenomenon takes place due to the non-zero interface stress *f*, which increase the total energy of Cu/W interfaces. The modified Young equation is:

$$\cos\left(\varphi/2\right) = \frac{\gamma_{W/W}}{2(\gamma_{int} + f\varepsilon_{int})}$$

ε_{int} is the Cu/W interface strain



The interface stress *f* asymptotically approaches zero value in the temperature of 650 °C. When *f* becomes zero the Young equation of wetting returns to the conventional form. The temperature of 650°C coincides with the 700-800°C temperature range, when the degradation is experimentally observed

It was experimentally derived that the magnitude of interface stress linearly decreases with the rise of annealing temperature as the residual stresses in Cu and W nanolayers are relaxed