Direct micropatterning of Cu using polymer electrolyte membrane stamp

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Cu is widely used in the fabrication of metal interconnects for electronic devices such as integrated circuits and printed-circuit boards because of its low resistivity and good thermal stability[1]. Furthermore, Cu can be used as a substrate for graphene growth, and graphene nanostructures have been achieved using patterned Cu substrate[2]. Due to superior pattern resolution to other direct patterning processes, photolithography is generally used to prepare patterned Cu surfaces. However, photolithography is complex and has a high environmental impact because of the multistep process with the need for resists and harsh chemicals. To avoid this problem, we establish a direct electrochemical imprinting process that generates micropatterns on the Cu surface in a single step without the need for resists and harsh chemicals. In this process, a polymer electrolyte membrane (PEM), which is an ion-conductive polymer material, is used instead of the liquid electrolyte. A Cu/PEM/cathode electrochemical system is proposed to form the pattern on the Cu surface by the selective electrochemical etching that occurred at an interface between PEM stamp and Cu (Fig. 1(a)). PEM stamps with various patterns such as sharklet, lattice, and line-and-space structures were prepared via hot embossing. Patterning characteristics were investigated on the surface of Cu thin film deposited on a glass substrate. Scanning electron microscopy and atomic force microscopy indicate that the Cu surface in contact with the PEM stamp is selectively etched to form the pattern structure (Fig. 1(b)). The depth of the resulting pattern structure matches the thickness of the Cu film, indicating that etching by the electrolysis automatically stopped when it reaches the glass substrate. The proposed electrochemical treatment is an environment-friendly and cost-effective approach because it is a simple direct imprinting process that does not employ resists and harsh chemicals. Furthermore, it is expected to increase the efficiency of microfabrication such as metal interconnects because the micropatterns can be formed on the Cu surface in a single step without the need for a complex multistep.

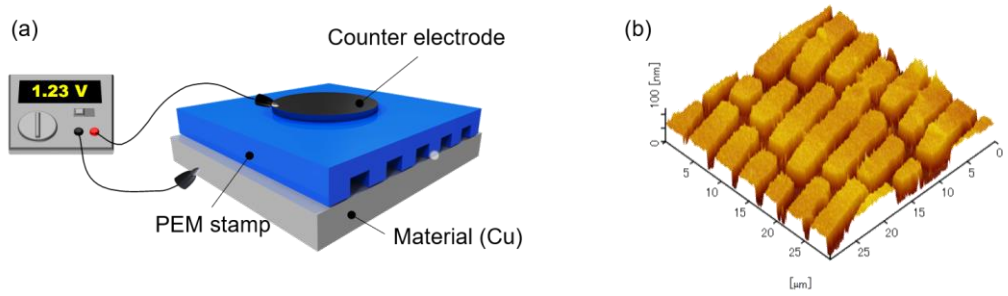

Fig. 1 (a) Schematics of the proposed patterning process, (b) atomic force microscopy image of micropattern formed on the Cu surface by the proposed process.

1) Jenny Rickerby, Joachim H.G. Steinke, *Chemical Reviews*, **2002**, *102*, 1525.
2) Min Wang, Lei Fu, Lin Gan, Chaohua Zhang, Mark Rummeli, Alicja Bachmatiuk, Kai Huang, Ying Fang, Zhongfan Liu, *Scientific Reports*, **2013**, *3*, 1.