Directed, Liquid Phase Assembly of Patterned and Thin Metallic Films by Pulsed Laser Dewetting

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Self–organizing materials offer the potential to assemble complex systems by defining only the *initial and bounding* conditions if the fundamental scientific principles guiding the assembly are known. A lot of work has been done studying the assembly of continuous thin polymer and metal films which reveal interesting dewetting phenomenon. While the break-up and pattern formation via dewetting of continuous thin metal and polymer films has been studied in detail, less work has been devoted to the dewetting and pattern formation of confined or patterned thin films. In this work, nickel and nickel/copper thin films were patterned into various shapes and treated via nanosecond pulsed laser processing. Liquid phase dewetting produced 1D and 2D features unique to *patterned* thin films. Thin nickel patterns of a variety of sizes of circles, squares, and triangles were achieved by a conventional lift-off process. The edges and vertices of the patterned shapes act as programmable instabilities which enable directed assembly via dewetting when the laser energy density is above the melting threshold. The evolution of nickel line instabilities and nanoparticle formation with correlated size and spacing were observed as a function of the number of laser pulses. Nonlinear time–dependent simulations and linear stability analysis based upon a simple hydrodynamic model were employed to understand the instabilities that direct the nanoparticle assembly. In addition, binary thin films were deposited and dewetted in order to yield nanoparticles of adjoining Ni and Cu hemispheres as well as to study the binary, liquid phase alloying dynamics.

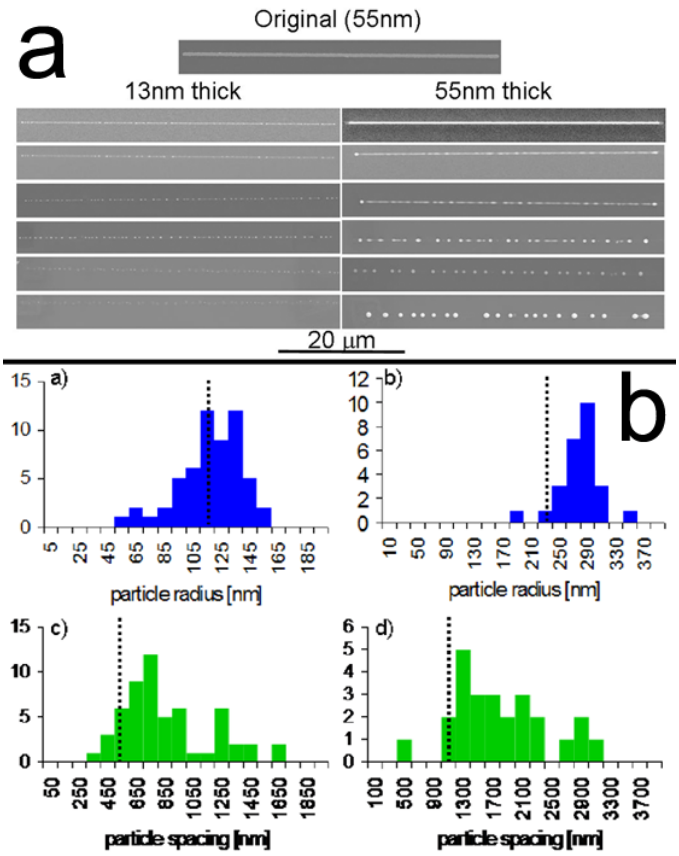

Figure 1 (a) SEM images of 50 µm long, 420 nm wide and 13 nm (left) and 55 nm (right) thick Ni lines after 1, 2, 3, 5 and 10 laser pulses progressing from top to bottom.

Figure 1 (b) Histograms of the resultant particle size (a, b) and the particle spacing (c, d) of the 13 nm (a, c) and the 55 nm (b, d) Ni lines. The data were taken after 5th and 10th laser pulse for 13 nm and 55 nm lines, respectively. Dotted lines show the predictions of the linear stability analysis

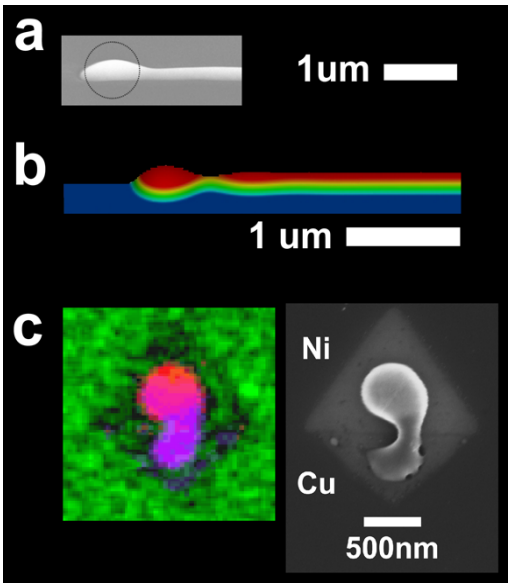

Figure 2 (a) The initial stages of laser induced dewetting. A single 248nm laser pulse, pulse width ~25ns and an energy density of 420 mJ cm^{-2}. SEM image showing the terminus of a nickel line 55 nm thick that was dewetted following the single irradiation pulse. Image acquired at 45^{o} (b) Simulation of (a) after 35ns of liquid lifetime (~ 1 laser pulse). (c) Nickel and copper thin films (30 nm) were patterned to flow (down and up in the image, respectively) in response to laser–induced dewetting to facilitate alloy nanoparticle formation. Auger electron spectroscopy composition map shown (left, red = pure Ni, blue = pure Cu) at left indicates alloying (1 pulse)