Nanotrench Filling Via Planarization by Laser Assisted Direct Imprint (PLADI) and Air Cushion Press (ACP)

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Planarization by laser assisted direct imprint (PLADI) has been demonstrated as an effective, fast, inexpensive method to fill nanoscale holes and vias [1-2]. It is not only much cheaper and faster than atomic layer deposition (ALD), but also can apply to the materials that ALD does not apply. To successfully use PLADI in IC and other manufacturing, uniformity over wafer-scale area is needed. On the other hand, Air Cushion Press (ACP) has been demonstrated to be an effective tool to achieve a wafer-scale uniformity and repeatability, and lengthen the mask life in nanoimprint lithography [3]. Here, we report a demonstration of a new approach to trench filling that combines PLADI and ACP.

Figure 1 shows key four steps of PLADI in nanotrench filling. First, a material to be filled (semiconductors or metals) is deposited on a substrate with nanotrenches and nanoholes. Due to the small opening of the nanotrences and nanoholes the deposited materials will stay at the opening but not fill inside. Second, a flat plate (UV transparent) is pressed into the sample by an ACP. Third, a homogenized laser beam shines through the pressing plate to melt the filling material layer within 1 ns. Since molten semiconductors or metals have a viscosity near or blow water, the molten materials will flow, an external pressure, into the nanotrench and filling them in less than 300 ns. After solidificaiton, the flat plate is separated from the substrate.

In our experiments, SiO_2 on single crystalline Silicon wafer was used as substrate with the nanotrench of 100 nm wide and 150 nm deep. An e-beam evaporation deposited a metal or semiconductor film. A KrF excimer laser with a wavelength of 248 nm and operating at 1-50 Hz was used for this study. An air cushion press chamber was designed to apply a uniform press between the sample and the mold during laser melting of the seed layer. The filled trench was optimized by adjusting the laser melting and press parameters.

Trench filling was examined using various analytical techniques including scanning electron microscopy, and atomic force microscope. Figure 2 shows preliminary experimental results of nanotrench. 200 nm thick Al was initially depostied on nanotrench. A trench filling of Al was carried out at the laser fluence of $0.7J/cm^2$ and air cushion press of 100 psi. From SEM observation, the Al completely filled into nanotrench by PLADI. The mechanism of laser melting and air cushion press is being analyzed. We found different laser fluence and air pressure is required for different filling materials. The results of trench filling, uniformity, and surface roughness using ACP under different process parameters will be reported.

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[3] H. Gao, H. Tan, W. Zhang, K. Morton, and S. Y. Chou, NanoLetters 6 (11): 2438-2441 (2006).

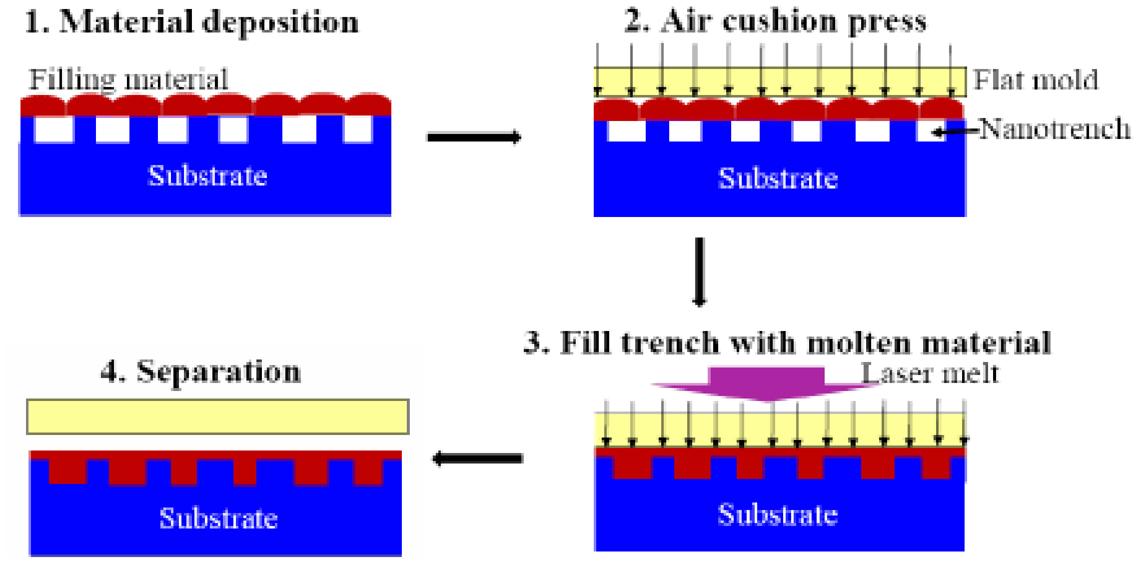

Figure 1. Schematic of PLADI and ACP process to fill nanotrench on a hard material surface.

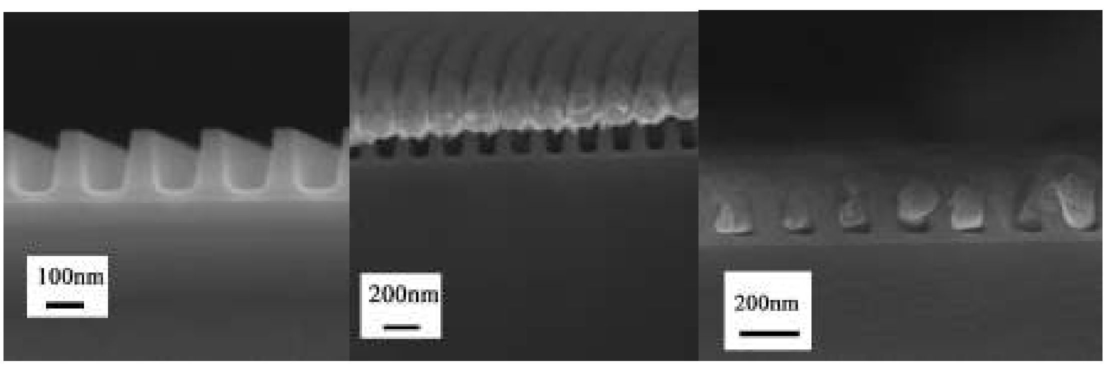

Figure 2. SEM image of the fabricated nanotrench of 100 nm wide and 150 nm deep in SiO_2 on Si substrate (a), Al is deposited on the opening of the nanotrench (b), and completely filling of Al into the nanotrench by PLADI (c).