Enhancement of thermal and photo-thermal carbonization of polymers by focused ion beam implantation of gold

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Ion implantation of transition metals is a promising approach to catalytic synthesis of carbon nanomaterials [1]. Prior studies also explored formation of conducting polymers [2] and plasmonic nanoparticles [3] by low energy implantation of gold. However, to the best of our knowledge focused ion beam implantation of gold has not been used to enhance pyrolytic conversion of polymers into carbon-based materials for on-chip applications in sensing and MEMS applications. Although pyrolysis of polymers is a well-established technology used in a broad range of industrial applications ranging from production of high strength carbon based structural composites to electrochemical sensors, integration of such pyrolytic carbons with on-chip electronics and nanoscale systems remains a substantial challenge. The key part of this challenge is the high temperature required for a complete pyrolytic conversion of polymer precursors into carbon. For instance, pyrolytic conversion of 3D-printed polymer structures into high quality carbon micro- and nano-electrodes suitable for electrochemical sensing involves annealing at temperatures in the range of 900-950 C [4].

Here we explore ion implantation of gold into polymer to enable carbonization of polymer precursors without exceeding the temperature range compatible with CMOS processing and to make it potentially compatible with flexible electronics MEMS technology. We selected a high-performance e-beam resist ZEP520 (Zeon, Inc.) as a model polymer for this study. Our findings show that exposure of ZEP520 to a focused beam of Au^{++} with energy of 35keV using Raith Velion system drastically changes its Raman spectrum (Figure 1, curves 1 and 3) and facilitates its subsequent carbonization under photothermally induced pyrolysis. More specifically, we found that while no changes are observed in the areas of the native ZEP520 exposed to a focused HeNe laser beam, the same laser beam exposure caused carbonization of the gold- implanted ZEP520 comparable to that achieved when the polymer was annealed at 950C (Figure 1, curves 2 and 4).

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References

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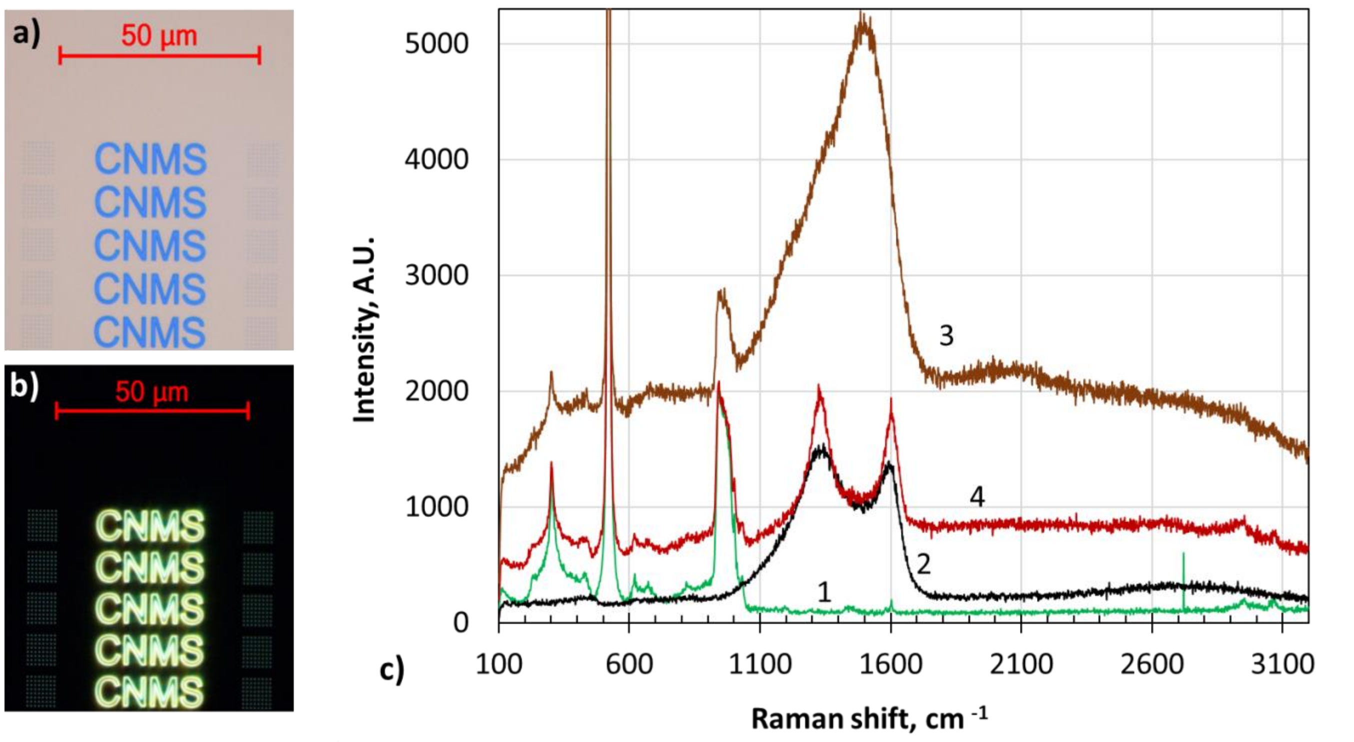

Figure 1. Bright field (a) and dark field (b) optical images of ZEP520 e-beam resist on a Si chip exposed to Au^{++} focused ion beam in a "CNMS" patterns with a dose of 1000 $\mu C/cm^2$ and (c) Raman spectra of (1) ZEP520 e-beam resist on a Si chip, (2) the same resist carbonized at 950 C in Ar for 10 min, (3) the same resist after Au^{++} focused ion beam exposure, and (4) after additional localized HeNe laser beam exposure (10mW power, focused on approximately 1μm^2 area for 15 sec).