Electron Beam Induced Deposition of Platinum Contacts

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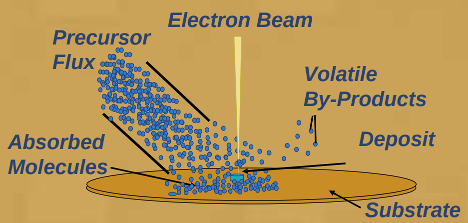
Nanoscale Material Integration

The integration of non-conventional materials such as polymer fibers into integrated circuits of the future could greatly improve performance and functionality. Electron beam induced deposition (EBID) is being investigated as an approach for achieving such integration.

Process Theory and Implementation



- A precursor gas is directed onto the substrate surface.
- Interaction between the electron beam, substrate, and absorbed precursor molecules deposits metal.
- EBID does not damage substrate or implant it with ions.

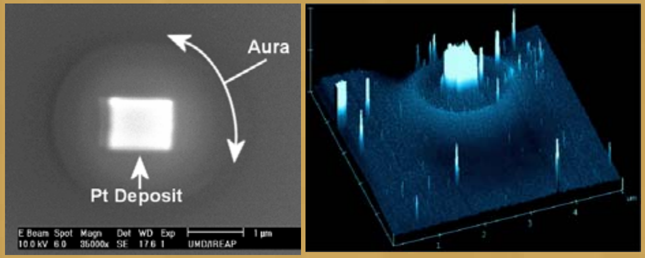
Novel Precursor Gas

- Organic (carbon-containing) precursors deposit large amounts of carbon which degrades contact quality.
- A novel inorganic precursor, **$Pt(PF_3)_4$**, minimizes carbon contamination in deposits for resistivities of ~3 times pure Pt.

Challenges and Accomplishments

Challenge 1: Aura Formation

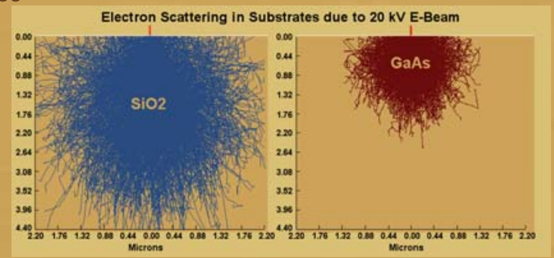
Undesired auras form around EBID-formed Pt deposits.



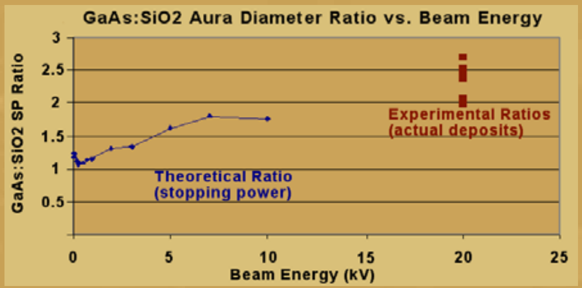
Hypothesis: secondary emission of electrons causes auras.

Accomplishment 1: Aura Mechanism

Below: Monte Carlo simulations of electron scattering suggest aura sizes should differ in different substrates.



Hypothesis tested by comparing theoretical vs. experimental aura diameter ratios on SiO_2 and GaAs. Theoretical ratios were derived from substrate stopping powers (SPs), which are used as proxies for aura diameters.

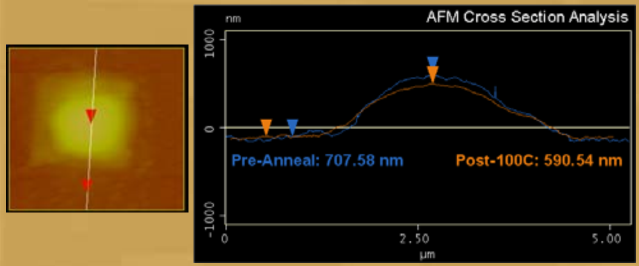


- Experimental ratios match theoretical SP trend, suggesting secondary emission is the aura formation mechanism.
- Possible solutions: low beam energies and thin substrates.

Challenge 2: Effects of Annealing

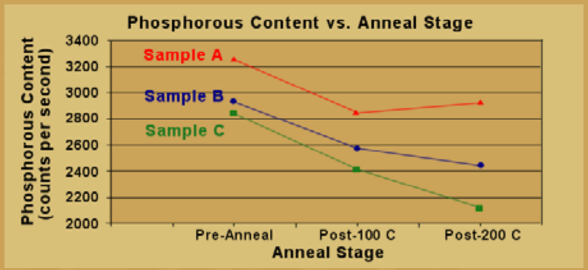
Previous experiments indicated that annealing contacts may improve metal quality. The cause of improvement is tested here on Pt deposits made with EBID.

Accomplishment 2: Anneal Effects Analyzed



~ 16% reduction in deposit height following 100º C anneal.

Energy dispersive x-ray analysis reveals trend of decreasing Phosphorous content following anneal:



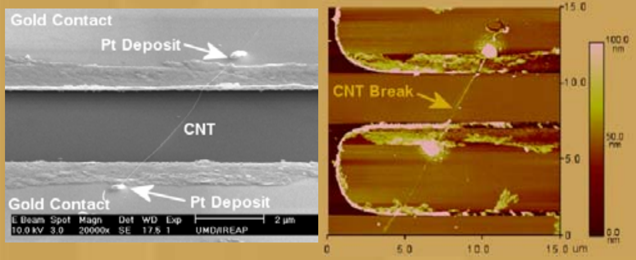
Results suggest annealing expels P from Pt deposits, thus raising density and possibly improving contact quality.

Challenge 3: Integrating Carbon Nanotube

Incorporating a CNT onto a circuit defined by two Au contacts would strongly demonstrate EBID's integrative capabilities.

Accomplishment 3: Integrative Capabilities

A carbon nanotube was transplanted onto two Au contacts. EBID provided mechanical and electrical Pt contacts.



Above Right: CNT breaks following resistance measurements, indicating successful passing of current through circuit.

100 C anneal improved circuit resistance from ~520 Kohm to ~290 Kohm. This confirms EBID's integrative capability as well the benefits of low-temperature annealing on Pt contacts.

Conclusion

EBID, used in conjunction with $Pt(PF_3)_4$, has shown much potential as a means of integrating nanoscale materials into circuits. By understanding the aura mechanism and the effects of annealing, contacts may further be improved to provide greater deposition precision and contact quality. This allows for a reliable, high-quality process of device integration.