

Publishable summary of the 1st period of the CopPeR project

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1 Publishable summary

Introduction and General Technical Goals

The collaborative FP7 ICT STREP CopPeR (Copper Interconnects for Advanced Performance and Reliability) project aims to develop a novel copper deposition process based on the use of non-aqueous solvents – more precisely of liquefied ammonia and ionic liquids - in order to overcome the limitations of currently applied interconnect formation processes enabling further device scaling beyond the 32 nm technology node. The scheme for this novel interconnect processes consists of a barrier pre-conditioning, a seedless copper deposition as well as a copper post-treatment. This non-aqueous process will open novel routes to implement direct-on-barrier plating, focussing on tantalum as diffusion barrier. The process developed and implemented within the CopPeR project aims to significantly improve the quality of the Cu metallization due to the fact that the conductivity limiting seed-Cu will be eliminated and thinner barrier films can be applied, e.g. by ALD (atomic layer deposition); so more volume is available in trenches for high quality, low resistivity Cu.

Description of Work done in the first year and results

The project started in January 2008, it is running for 30 months and it consists of three phases whereby in the first phase, which corresponds to the first project year, the focus was put on the analyses and selection of materials and the cell design.

Therefore first of all in WP 1 the requirements for copper interconnects and barrier layers to be integrated for future nodes during the project, were defined. The electrolytes – the solvents and their supporting ingredients, the wafer materials used as substrates as well as barrier materials were characterised with regard to their ability towards the aimed non-oxidizing, seedless deposition approach. Especially liquefied water free ammonia was investigated as solvent for the direct-on-barrier plating process and several salts and additives were investigated to optimise the plating results. Thus a plating bath formulation was defined.

The focus of research in terms of barriers was laid on Ta/TaN barriers, whereby Ru barriers were used for comparison purposes. In addition basic physical properties were investigated, deposition methods (with a focus on electrolytic copper deposition in the first year) were assessed, and test structures of the wafers were designed. Several supporting electrolytes were investigated for achieving a high conductivity of ammonia based plating baths. Additives for improving adhesion and enabling superfilling were screened. As a main result of these research activities a formulation for copper deposition, which meets the required deposition rate, was achieved.

On the basis of these findings as well as of various modelling and numerical simulation work on the complex mechanism of electrodeposition based on multi-ion macro-models for copper deposition a deposition cell design was proposed in WP 2. The aim was to develop a preliminary design for a 300mm plating cell. Therefore a potential model was developed for the non-aqueous copper deposition process - based on the cathodic and anodic polarization in the relevant process window. Simulations showed that a standard fountain plating cell yields a quite non-uniform deposition over the wafer, which is due to non-negligible stray currents through the stainless steel of the plating chamber. Because of this unwanted effects an electrical isolation of the walls was necessary. So a new improved cell concept was developed. Additional modifications will provide further improvements to the uniformity of deposition and to control the deposition process. The WP2 team also started to develop

and design several elements such as the counter electrode and different types of reference electrodes.

In parallel WP 3 started to develop the process for copper deposition from non-aqueous solvents. Deposition from liquefied ammonia was developed resulting in a plating bath based on ammonia salts as supporting electrolytes, complexing agents acting as adhesion intermediary and superfilling additives. The deposition of copper seed layers from ionic liquids was investigated under vacuum to exclude any traces of water and oxygen. Special aspects like the nucleation density and uniformity as well as the repeatability in deposition have been investigated in more detail – the nucleation potential was one main issue in this aspect. The effect of additives on copper nucleation and adhesion of deposits was studied and clear differences of the behaviour of additives in ionic liquids and aqueous electrolytes were observed. WP 3 did a series of plating experiments in order to improve specific aspects; afterwards the formation of closed copper layers was analysed. In addition in WP 3 the partners aimed to develop a detailed multi-ion model that takes into account all the relevant phenomena in copper superfilling from non-aqueous solution. Therefore the electrochemistry solver had to be extended with basic models for ionic transport in ionic liquids. Furthermore a grid generator capable of tackling small spatial scales as well as new algorithms describing nucleation and adsorption processes had to be developed. The last subtask to model the superfilling process is the integration of electrode shape-change algorithms, which will be done in the next period. As the main result of these research activities in the first project year a preliminary list of additives suitable for superfilling has been compiled.

The focus of WP 4 laid on the design of the prototype which affects the different components: pressurized deposition chamber, the pressurized mixed tank, the piping and instrumentation, the salt ports and the chuck. The research activities are based on the simulation results of WP 2 and consider the necessary flexibility of the design to accommodate and position the complementary or supplementary counter and steerable anodes. The chamber design has been finished, draft chuck designs for processing 300 and 200 mm wafers were created and a P&I flow plan defined. The manufacturing of the autoclave (full scale plating chamber prototype and ammonia storage tank) has begun during M10. The chamber installation will take place most likely during the second quarter of the year 2.

In WP 5 a major task was dealing with the nano-characterization of samples in general and with the element specific analysis of sub 10 nm thick interfacial layers – especially the presence of oxygen in the copper-tantalum interface. A combination of techniques offering high spatial resolution and analytical sensitivity was evaluated to enable adequate analysis of the deposited films and interfaces. Among other things a set of acquisition parameters for qualitative analysis has been identified and high resolution phase contrast imaging for structural and crystallographic investigations are available.

As a result of all the research activities in the five technical CopPeR project workpackages during the first project year, a baseline definition of the geometry for the first 300 mm cell design has been reached.

The next phase will focus on the development of the copper deposition process based on the findings from phase one with the additional support of micro-modelling. The process will be scaled and integrated into a 300 mm proof-of-concept. In the third and final phase, the process will be integrated into a complete interconnect scheme, and optimized according to the industrial chip manufacturer's needs.



The CopPeR project has successfully proven direct-on-barrier plating from non-aqueous solvents. The CopPeR deposition process is facilitating advanced interconnect designs without the need for deposition on a PVD seedlayer.

CopPeR Project Partners

The final goal of the CopPeR project will be achieved through collaborations within a very strong consortium based on a team with outstanding scientific, engineering and manufacturing qualifications. The consortium consists of 8 European leading companies and academic institutions (Technikon Forschungs- und Planungsgesellschaft mbH (AT), SEZ AG (AT), Katholieke Universiteit Leuven (BE), FELMI - Technische Universität Graz (AT), ELSYCA N.V. (BE), Vrije Universiteit Brussel (BE), Infineon Technologies AG (G) and Cormet OY (FIN)). Together they represent a vertically integrated consortium, with excellence in plating technologies and knowledge stretching from basic research to the design and marketing of products. This includes the production, evaluation and impacts on the ITRS Roadmap as well as intimate knowledge of the end-user market.

CopPeR Project Consortium

The total volume of the project is estimated to be 4.7 Million Euro, part of which will be contributed by the EC. For more information about the CopPeR project please visit the project's website **www.copper-project.eu** or contact

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Figure 1: CopPeR Consortium at Kick-off-Meeting in Villach February 2008

CopPeR Logo



Figure 2: CopPeR Logo

CopPeR Disclaimer

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