Metallic submicron wires and nanolawn for microelectronic packaging. Concept and first evaluation.

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ABSTRACT

Starting with a brief review of submicron wire production techniques, promising applications of submicron and nano wires are discussed. Observed attractive properties of metal rod decorated metal surfaces, so called nano lawn, for low energy joining and flip chip bonding are presented. The potential of these materials for microelectronic packaging by decoration of joining parts is shown: Due to close proximity of different grain sizes in intercalated nanolawn pieces (joining partners) recrystallization phenomena can be used for fluxless joining. Thus, new strategies for electrical interconnection of functional components can be designed by choice of morphology and composition of galvanically cast metal rods and wires. The experimental proof of principle has been performed with gold nanolawn. Based on original work new applications are presented. Related use of structures decorated with submicron wires and nanowires is discussed for microsystem technology.

Keywords: nanolawn, nano wires, nano interconnects, flip chip

1 SUBMICRON WIRE PRODUCTION TECHNIQUES

The functions of nanowires (NWs) which can be developed by suitable microelectronic packaging lay mainly in interconnect formation, sensorics, and photonics. With the common understanding of a wire, NWs would be expected to be cylindrical conductive strands with diameters < 100 nm of infinite length. Whereas common wires are drawn from one single metal, those NWs cannot be drawn and do not necessarily consist of one single material only. As different the materials as different the techniques to produce corresponding wires. Although rod-like colloidal particles [1] are often mentioned as NWs in the literature, they should rather be regarded as rods or crystal needles. Electrically conductive carbon nanotubes also have been presented for wiring purposes [2]. We will focus there exclusively on metallic wires and wire-like structures, e.g. pillars standing on a substrate or lawn like structures generated by template techniques and rods, "mown" from those "lawns". A simplified comparison of NW generation principles is shown in table 1.

wires	*‚usual' w.*	*nano wires*
PROCEDURE	drawing	wire growth and writing
STARTING MATERIAL	bulk rods	single building units
BUILDING UNITS	n.a.	cations, atoms, clusters (NC's, NP's, rods)
ENERGY BALANCE ?	positive	negative chem. reduction & bonding, assembly
PHASE TRANSITIONS	none (~crystallinity)	cryst. growth from ions or atoms VLS / LS / SLS
DRIVING FORCE	mechanical	external force gradients DC: ELPHO / Plating AC: DEP i.e. inhomog. E-fields
TEMPLATE	drawing plate	w/o external internal
TEMPLATE MATERIAL		molecules hard soft polymer

Table 1: Wire generation: Classical wires vs. NWs.

Even "template free" techniques are characterized by a certain soft barrier: Specific crystal growth directions are shielded by low molecular weight adsorbates. We follow the depicted in Fig. 1 scheme to produce wires and lawn, using "hard" polymer exotemplates. Practically important nanoporous exotemplates are AAO and TEM (See below).

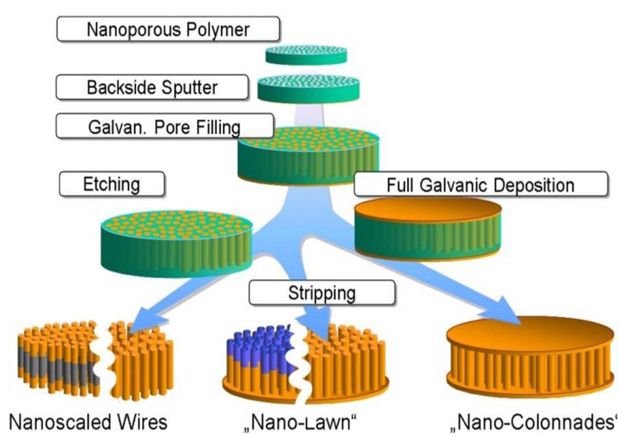

Figure 1: The nanolawn pedigree.

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1.1 Anodically oxidised aluminum (AAO)

Electrochemically tunable nanopores in a rigid matrix like aluminum are the ideally hard exotemplate. Pore filling with metals by galvanic plating [3] or with pressurized molten metals seems to be suitable for mass fabrication [4].

1.2 Etched particle track polymer membranes

Since these materials are commercially available as size selective filter membranes, they represent a cheap and easily accessible template. Etched particle tracks in polymers [5] have been galvanically filled at first for analytical purposes [6] and later on explored for different applications [7, 8, and others]. As pore size and shape can be varied [9], and polymer composition can be tuned, they became popular for different applications in nanotechnology. Adhesivless basic materials for flexible PCBs have been presented recently [10]. Other industrial applications have been reviewed by P. Apel [11]. Galvanic metal deposition in such pores has been in the focus of R. Neumanns group at GSI Darmstadt [12, 13].

2 MORPHOLOGY OF NANOLAWN

Depending on pore diameter, orientation and density, different nano lawn morphologies can be generated. Fig. 2 shows single metal structures, fabricated with polycarbonate filter foils (Pore diameter 600 nm). If the pores are oriented perpendicular to the membrane plane, a high amount of free standing single wires can be prepared.

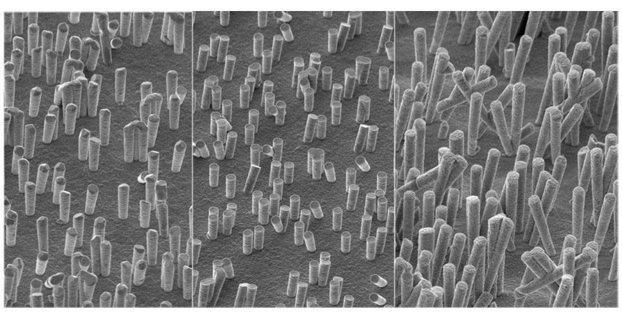

Figure 2: Single metal lawn. From left to right: Au, Pt, and Ag rods, 600 nm diameter. Note different crystallinity.

We used both membrane types with different pore density for the generation of bimetallic wires (See Fig. 3). Under certain conditions single crystal (grain) growth occurs, paving the way towards promising new applications.

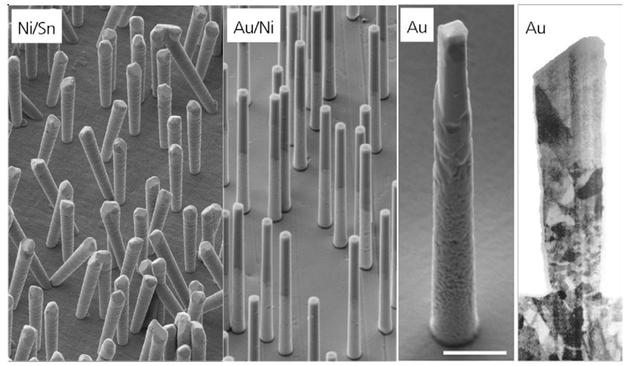

Figure 3: Bimetallic and single crystalline wires (FIB-SEM)

3 APPLICATION POTENTIAL

Especially monodisperse nanowire preparations may be attractive for advanced packaging by generation of

• active and passive photonic [14,15] or HF structures [16], stop-band filters, or antenna structures [17-19],

• for nanowire arrays and stacks to built-up logic and memory circuitry and devices [20-22], for applications in molecular electronics [23] and electronic olfaction or magnetic sensing [24],

• for nanowire arrays as nanoelectrode ensembles (NEE) or nanodisc electrodes with enhanced sensitivity in wet electrochemical and gas analysis [25,26], or as field emitter [27-31]. We have been proposing the use of nanolawn for low temperature joining [32]. Now extend the concept towards a generalized approach and technological principle.

4 LOW TEMPERATURE JOINING BY NANO INTERCALATION BONDING

If galvanically cast nanolawn foils (Comp. Fig. 1) are joined by intercalation face-to-face, grains of different size along the wires of both joining partners are brought into close proximity. During a subsequent annealing step, recrystallization effects cause growth of common grains. Fig. 4 shows the NIB concept for nano lawn, other nano-structures can be intercalated as well.

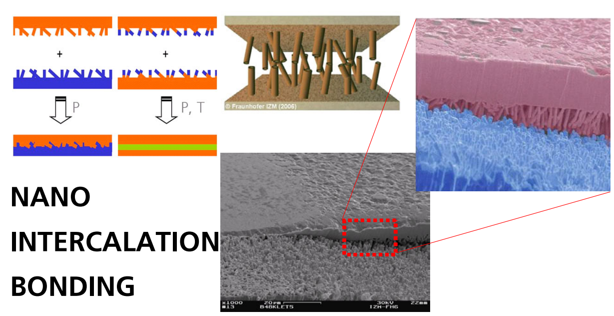

Figure 4: Principle of nano intercalation bonding (NIB).

Depending on pressure applied, different proximities of intercalating structures combined with plastic deformation at sliding surfaces have been observed (Fig. 5).

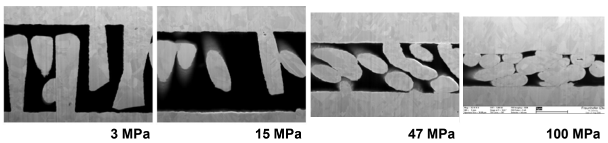

Figure 5: Applied bonding pressure for gold nanolawn. FIB-SEM analysis

With rising annealing temperature or/and duration we observed complete fusion at the contact zone, resulting in a fluxless soldering like bonding process (Fig. 6).

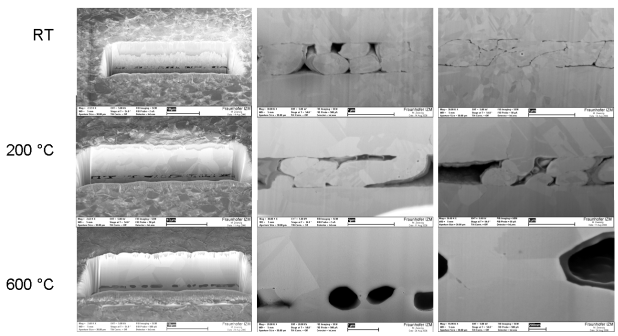

Figure 5: Grain growth with annealing. Joining partners (top and bottom) have been bonded at 100 MPa. Samples have been cut (FIB-SEM).

5 CONCLUSION

If the joining, i.e. bonding pads of flip-chip parts can be fractally structured or otherwise nano-sculptured, recrystallization processes after or even during joining can be used to produce single metal or metal alloy interconnections in a fluxless process.

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