Koops-GranMat® for field emitter and detector applications

Hans W.P. Koops

HaWilKo GmbH 64372 Ober-Ramstadt, Germany
hans.koops@t-online.de

Darmstadt, Art Nouveau Centre, brought a new arts at Expo 1902, 1904

At German Telekom Research Centre FTZ in 1994 a new material was discovered:

It can replace cooled superconducting materials in present applications and will revolutionize electronics, THz switching, photonics, and energy transport

Electron beam induced deposition and etching is used to produce Koops-Pairs in Koops-GranMat® using an 3 - d Nano Printer

- Adsorption of precursor molecules
- Exposure with focused charged particle beam (60 MW/cm²)
- Pixel exposure dwell-time must be > 10 msec
  - Reaction and Immobilization of Precursor → Deposition
  - Reaction with Substrate and Volatilization → Etching

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HaWilKo GmbH

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3-D Lithography uses x, y, and t beam control for Koops-GranMat®.
Lithography systems with GDSII-layout exposure control can not return to a position with a changed dwell time. This requires loading a new pattern file. Therefore FEBIP/GDSII deposition systems failed to build Koops-GranMat®.

Illustration of FEBID / GDSII:
Stepping time 100 nsec /pitch
Dwell time < 14 μsec
Koops-GranMat® Metal crystals in Fullerene – C -- matrix

Dimethyl-Gold-Trifluoro-Acetylacetonat

Cyclopentadienyl-Platinum-trimethyl

Molybdenum Hexa-carbonyle

Nanogranular material

The ratio of refresh-time to dwell time renders a less dense deposit, and no longer a condition to form Koops-GranMat®

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HaWilKo GmbH

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Motivation: Novel nano-granular matrix materials for FE- Nanofabrication are needed

Characteristics: High current density (GA/cm²) at 1 mA in a wire of 70 nm diameter, at room temperature without thermal destruction.

Solution: Field emitter tips from materials with Bose-Einstein Condensation at Room temperature deliver a current density up to 3 GA/cm² in a total current of 1 mA at >10 MV/cm field strength at the tip of 10 nm radius at < 70 eV extraction voltage from a spot of 2 nm diameter.

Material: A sinter process under e-Beam exposure renders metal nanocrystals with a diameter of 2 nm (Pt/C) or 4 nm (Au/C) with 1 nm distance which are embedded in a Fullerene matrix. Pt/C and Au/C form a common Fermi energy level. Metal: negative charged, C: positive charged. Electrons and holes form Koops-Pairs. For geometry reasons, the crystals cannot transport high phonon energies, but only <2 meV, which corresponds to < 23 K, as it is required for High TC Superconductors.

New Name: Koops-GranMat®, is composed by Koops-Pairs, formed by excitonic energy level electrons (-, Spin up), and holes (+, Spin up), which form immediately Bosons (Charge 0, Spin 2), and are coherent.
Focused Electron Beam Induced Processing (FEBIP), (0.5 nA, 20 kV, spot 2 nmØ) produces nanocrystalline deposits (percolating Metal-, -oxide, –nitride crystals in a mixture), or Metal single crystals in Fullerene – C – matrix from Cyclopentadienyl-Pt, or Au-tri-fluoro-acetylacetonate at a Rate of 1 µm / min @ 100 Monolayers/sec molecule supply rate. These compound materials are name protected as Koops-GranMat®

The deposit – Metal and Carbon crystals percolate and form a common Fermi level at ca. 5 eV. This charges Pt (Work function W= 5,1-5,9 eV) or Au (W= 4.9 eV) negative and the C- matrix positive (W= 4,81 eV). Contact : Au (W= 4.9 eV);

Excitonic surface orbitals around the Pt-crystals overlap and form the one energy level throughout the material needed for a Bose-Einstein Condensate (BEC). Electrons in the Pt excitonic surface orbitals and holes in the C-matrix, having parallel spin can form Bosons (Koops-Pairs: e-,h+, parallel spin) and occupy the BEC with millions of Bosons, like in lasers. Koops-pairs are similar to Cooper pairs, but have just reversed polarities.

Crystals of < 4 nm diameter result in a geometry quantization for acoustic phonons with energy < 2 meV (23 K). The material is super-cool! This leads to Hyper Giant Conductivity Observed at Room Temperature.
Experimental evidence of the repeatable production of Koops-GranMat® over the last 20 years

<table>
<thead>
<tr>
<th>Review FEBIP</th>
<th>MA/cm²</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt/C wire</td>
<td>100</td>
<td>J. Sellmair, NaWoTec, communication</td>
</tr>
<tr>
<td>HTc Superconductors</td>
<td>40 K</td>
<td></td>
</tr>
<tr>
<td>Titan doped Mg B₂</td>
<td>&lt;1</td>
<td>P.C. Canfield, D. Budko, Spectrum d. Wiss. Juni 2005 p. 56</td>
</tr>
</tbody>
</table>
Applications

Dots as Calibration pattern

Rods for photonic Crystals

STM 3- Point tip for AFM sidewall probing

Resistive arch

IR antennas

Electron source with low capacitance (24 aF)

H.W.P. Koops et al. 1997 at Telekom Research Centre, FTZ Darmstadt, Germany

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Superconductivity – Charges and Spins (Magnetons) balance each other (New BCS)


For Superconductivity a quantum collective wave, the condensate, is formed by a large number of electrons. A pair of electrons, a Cooper pair can form a Boson (Maxwell statistics). The “Pauli exclusion principle” only allows the existence of such a condensate if the waves which compose it are carried by particles called Bosons. In conventional superconductors, the creation of electron pairs and the formation of the condensate happens instantaneously.

Charge: 2e, Spin: \(1 - 1 = 0\). The dimension is up to 600 nm diameter. (CNRS)

2 Electrons repel each other, 2 Bohr Magnetons (Spin) attract each other. However that happens only, if no phonons destroy the e-e binding by high temperature lattice vibrations.

Therefore Superconductors must be cooled below TC!
Electrons move at high temperature. At lower temperature they form Cooper-pairs. They transit into the condensate where all particles are Bosons, and form finally a coherent phase. The estimated diameter of one Boson is 600 nm.

Conductance $G$ has a Negative Temperature Dependency due to **Hopping** in the contact area of the gold line to the deposited line.

Activation energy

( Pt/C: $\sim 125$ meV, Au/C: 65 meV)

RT

Approximated with Bohr’s model

Predicted $\Delta E$ between confined and overlapping orbits agree with observed $\Delta E_a$

**Bohr’s model**

Bohr radius: $r = \varepsilon n^2 \hbar^2 / (\pi m_{\text{eff}} e^2)$

Energy level: $E = - m_{\text{eff}} e^4 / (8 \varepsilon^2 n^2 \hbar^2)$

### Observed $\Delta E_a$

- **Pt:** 3nm - 125 meV
  
- **Au:** 5nm - 65 meV

### Graph Details

- **Exciton diameter ($r$) vs. $\Delta E = E_{n+1} - E_n$ (meV)**
  
- **Pt** and **Au** markers indicate experimental data points for observed $\Delta E_a$ values.

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Bose Einstein Condensate (BEC) forming Koops-Pairs

In Koops-GranMat® 2 Charges, Electron – and Hole + attract each other, 2 Bohr Magnetons (Spin) repel each other. However, the laws for repulsion or attraction stay the same, just the sign changes, therefore the sizes remain the same for BCS or BEC Bosons.

Such a Boson, however, has a strong dipole moment. The extraction voltage forms an electrostatic field with a field gradient. Dipole moment times field gradient represents a force on the dipole and moves the charged Koops-Pair. This moves the Boson until one part feels the field gradient at a FE-tip, and then the Boson decays, and releases the electron. The hole immediately catches the next electron and forms again a Boson. Since Bosons move without friction inside the Koops-GranMat® a huge current is flowing, as experimentally measured: 1 mA per emitter, at > 3 GA/cm² current density at the tip.

The calculated temperature for the Bose-Einstein-Condensation is higher than room temperature (300K), according to Remeika’s Theory (2012).
Molecular surface orbital computation can handle today ca. 300 atoms, but not >1000 per crystal, nor the interaction of > 3000 metal atoms with an intermediate carbon phase. Therefore a **semiclassical approach** is the application of **Bohr’s atom model** to explain excited surface Orbital states. Nanocrystal diameter Pt/C: 2 nm or Au/C: 4 nm. Overlapping electron states allow the formation of a **Bose-Einstein Condensate**, having 1 common energy state throughout the material. Electrons (-,↑) and holes (+,↑) combine to a Boson: (Charge 0, 2 magnetons, strong dipole moment), and leave the Fermi-Dirac statistics (only 2 electrons per energy state), to form **Bosons following Maxwell statistics**, allowing unlimited number of now coherent Bosons in the state.

![Diagram](image)

- **Bohr’s Eigenvalues for circular Surface Orbitals** (n \(\lambda\))
- **Bohr’s Eigenvalue transmission states** \((m\lambda/2)\)
- **Crystal surface** \(n = 3\), \(\lambda = 2\) nm
- **n = 4 exitonic orbital**, \(\Delta E 125\) meV
- **n = 5 overlaps to n = 5, 6 of next crystal**
  - this forms the energy level for the **condensate**
  - **n = 6**

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Koops-GranMat®: a cluster of excitons, explained by Bohr’s atom model

Due to Maxwell – Boltzmann temperature distribution of electrons in the dense states of the conduction band, electrons in the Au contact metal can have at room temperature a high energy and supply those to 5 to 6 \( \lambda \) Exciton orbits in Pt, and to the 7 to 8 \( \lambda \) exciton orbits of the gold crystals.

Since the excitonic energy levels in the BEC material are overlapped, also higher excited electrons can be in the higher levels even more overlapped. These levels allow to form a Condensate, and contain BOSONS from electrons and holes, having parallel spin, and contribute to the current carrying characteristics.

The Maxwell energy distribution of charges in thermal distribution supplies the current. If the current in the supplying contact area is not large enough the Gold contact area will melt.

Under an externally applied electric field with a gradient inside the material, the Bosons are moved to the contact, where they decay into electrons and holes. This separation of electrons and holes results in current transport and coherent emitted electrons.
Quantum Condensation Temperatures calculated after Remeika

Critical temperature calculated for BEC in Koops-GranMat® gives $\sim RT$ because of high density and small mass of electron

$T_c = 0.527 k_B^{-1} \hbar^2 (2\pi m_0)^{-1} (N/g)^{2/3}$

Excitonic BEC

Koops-GranMat
300 K, $b=2$ nm

2D double quantum-well
50 mK, $b=200$ nm

Boson atom BEC
(Rb)
0.5 $\mu$K, $10^{20}m^{-3}$
Coherent electron motion in EBID material

Pt deposit after O-RIE etch emits coherent electron interference


Electron motion in disordered granular metal prepared by EBID is coherent
(Ref.: M. Huth, D. Klingenger, Ch. Grimm, Uni. Frankfurt am Main, Germany, FEBIP 2008)

Intergrain Tunnel conductance $g = G/(2e^2/h)$
Intragrain conductance $g_0$
Single grain Coulomb charging energy $Ec = \sim 1/r$
Average intragrain level spacing $d = \sim 1/r^3$
Level width $\Gamma = \hbar/\tau_0 = g\delta$

Current is conducted by BOSONS
Significant features of Koops-GranMat®

(1) Negative temperature dependence of resistivity
(2) Photocurrent response – 3 x more efficient at 700 nm than Si solar cell in white
(3) High current carrying capacity (>50 MA/cm² current density, wires (50 nm), wires (70 nm) current density, wires (50 nm), wires (70 nm))
(4) High contact resistance due to hopping + tunnelling (< 0.01 Ohmcm)
(5) No heat damage (despite (3) and (4)), (> 1 GA/cm²)
(6) Low emission voltage. ( Au/C: 22 V, Pt/C: 70 V, Mo: 1 kV)
(7) Coherent electron emission from field emitter tip


Gold: 250 kA/cm²

It is a contradiction, that
Gold: resistance. 1 µ Ohm cm, carries Current: 250 kA/cm²
and Koops-GranMat®: Contact resistance 0.01 Ohm cm carries 50 MA/cm² on 70 nm diameter wire.
The high current density can be supplied by Gold at RT only via a large area tunneling contact from Gold to Koops-GranMat® by a Cone Foot point
Large area like for Copper( 2,5 KA/cm²) to Superconductors (<1 MA/cm²)
Applications of Koops-Gran Mat®

Electrons in vacuum are much faster than electrons in semiconductors: K. Shoulders 1956

This leads to Micro-tube applications in a miniature vacuum system.

Field emitter tips from Koops-GranMat® can deliver up to 1 mA, which is supplied from a gold conductor in a square area of 660 nm diameter.

Vacuum diodes and micro triodes of 1 µm length with a cathode to grid capacity of 240 aF allow operation as switching amplifiers above 3 GHz up to 6 THz with a high S/N > 6

Field emitter arrays can switch KA with 70 V using cm² large devices for power distribution

High current switch: 1 KA/ 0,7 x 0,7 mm² by an array of 1 Mio tips with 0,66 µm separation

Coating a glass or plastic fiber of 100 µm diameter with Pt/C and a layer thickness of 50 nm allows to transport current of 20 A per fiber with a current density of 1 GA/cm².

Thin large area deposited layers can serve as solar energy converters with a > 3 times higher efficiency than Silicon or other solar cells of today.

These layers can also serve as NIR infrared detectors, without cooling.
Giant emission current is obtained in vacuum electronics device made from Pt/C Koops-GranMat®. FN-plot shows field emission

Before emission Pt/C

After emission

Power density at impact 2 \(10^8\) W/cm²

Field Electron Emitters of High Brightness

Conductive tips deposited from $\text{Me}_2\text{Au(tfac)}$

Field emission microscope images. Full image W-tip and Supertip image (inset) The brightness of these sources is > 10 x higher than that of a Zr-O-W-emitter. The emission is confined to $\pm 7^\circ$ at a beam current up to 10 $\mu$A. (Schössler 1996)
EBID emitters have a smaller energy distribution
A possibility to fight Chromatic aberration in electron microscopy

EBID Field emitter materials are characterized by geometry quantization
Conduction is by coherent Bosons
Activation energy for Variable Range Hopping is 128 meV at 300 K
This level splitting energy is also estimated theoretically.

Tunnelling current is energetically split with level separation of 128 meV
Cold emitter FE-Energy-width 0.29 eV @ 300K
Linie width 20 meV?? Tbd!
Precursor Methy Pt Cpdy 3 Methyl, E-beam deposition in a FEI dual beam system Edinger (Uni Maryland): 1 mA current did flow through the 80 nm diam. wire. This corresponds to **20 MA/cm² current density** without destruction of the wire.
The mean free path between air molecules at 1 bar is 0.3 µm. A microtriode of 0.3 µm length does not require a vacuum pump, since there is ultra high vacuum between the gas molecules. The cathode-grid capacitance of a microtriode is in the range of fF. Such a system can switch and amplify in the upper 100 GHz regime.
Free Electron Laser a Tunable THz Source

(NaWoTec patent)
EBID NGM Materials, Resistivity, Photodetector

Resistivity can be tuned by dose beam energy and sample temperature.

Photoresistor-characteristics

I/U-Plot of a resistor being illuminated with intermission with white light.

Au/C resistor connecting two contacts.
Flat Camera for Multimedia Applications

“I look into your eyes, darling”

Multimedia requires a camera, which enables eye contact, while the operator observes the workstations screen.
Measurements on Pt/C show an influence on the conductivity by red, yellow and green light F. Floreani 12.05.2000 confidential
Nanocrystalline compound materials absorb light
Room-Temperature EBID NGM IR-Vis- THz detector

Metal single crystals in a carbonaceous matrix (Fullerenes) show high VIS light absorption

Pt/C :120 meV are needed for the excitation of one electron:
This means 1 red quant of 1300 meV can free 10 electrons!
Au/C : needs 60 meV to free 1 electron (1 Quant: 20 electrons !)

Using Pt/C NGM material solar cells due to geometry quantization Turanor would have needed less than 1/10 of the area = 53.7 m²
Instead of 537 m²!

X-ray imagers use Si absorbers, which require 1.5 eV per photon to release an electron. It is desirable to use NGM material absorbers in photon detectors with geometry quantized Eigenstates which release electrons absorbing 60 meV or 120 meV of the photon energy due to the structure generated by Mother Nature in the FEBIP deposition Process.

This could allow radiologists to use a 10 times reduced dose for all the x-ray investigations: Mammography, body and skeleton imaging, and could help medical diagnosis to be less destructive to the patient.
Miniaturized Orbitron Pump with utility space

HaWilKo Patent
Horizontal Anode Orbitron as chipmount device

- Ti Kathode
- Insulation
- Glass
- Emitter
- Extractor
- Ion mirror
- Deflector
- Anode
- Ion path
- Chip
Simulation of X-Ray source
with 30 kV Pt/C cathode 25 mA to Mo Foil with partial transmission and beam energy dump by retardation to 200 V, 0.6 W

Pt/C Tip array 600 nm pitch.
25 mA require at 100 µA per tip
an array of 16 x 16 tips
Emitter area 14 µm diameter
Deposition time ca. 100 min

A monochromatic Mo source for phase contrast X-ray imaging for mammography is possible

Size 10 x 20 mm
Mini-X-Ray tube with integrated Orbitron Pump and High-Voltage supply for Brachy-therapy

Electron sources
Orbitron

Metrology-Connectors

Orbitron anode

Insulators

Anode supply

Anode

Insulator

Encapsulation

Power

X-Ray tube-Fieldemitter Accelerator

HV-Cascade

Ground

HaWilKo Patent 2015

1 mm

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Confidential
Beams build Beams by EBID

Computer controlled deposition renders field emission Nano-systems. Source and 3 dimensional lens electrodes. The combination of the elements gives a miniaturized Nano-electron beam system, a 20 eV SEM. Deposition-Lithography works at 20 keV in a SEM and with 20 eV in a STM.

Vision:

One 20 keV system builds one 20 eV Nano-system on a chip with all functions. The 20 eV Nano-system builds a 20 eV System on a similar chip: N=2. 2 Systems build in parallel 2 more Nano-systems N=2² =4 systems. After 20 generations of Nano-systems building exist = 2²⁰ = 1 Mio. systems.

Sketch of Nano-System built by computer controlled EBID (NaWoTec Patent)
mm to IR Waves - Spectrum and Attenuation in Air

Fingerprints for explosives
THz Absorption Spectra (Finger-prints) of the explosives RDX, HMX, PETN, and TNT

(John Hopkins Univ. Laurel MD, Baltimore MD, USA)
Dynatron Oscillator

Dynatron vacuum tube Oscillator was invented by Albert W. Hull in 1918 at General Electric Res. Lab

- A Dynatron oscillator is a triode tube, which has a negative resistance.
- The negative resistance appears in triodes and tetrodes due to secondary emission from the anode, when the anode is operated at a lower voltage than the extractor grid.
- The emitted constant cathode current keeps an LC tank circuit oscillating by compensating the resistive losses in the LCR-circuit. A real resonant circuit is equivalent to an ideal capacitor, inductor, and resistor connected in parallel.
- The power supplied compensates for resistive losses and power extracted from the oscillator.
- The oscillation is self starting as the resonant circuit is excited by the inherent noise of the active device.
- The Dynatron tube is used as a transmitter oscillator for Radio waves

Dynatron THz source with forward and backward beam

FE Primary electrons generate at the anode secondary electrons SE. According to the energy of landing Primary electrons PE and the voltage swing of the oscillator around E, a net beam flies forward or backward between Grid and Anode. This charge emits THz radiation like an antenna without having a resistive wire.

The oscillator is charged by the field emission primary beam.

Negative I/V Characteristics:
Oscillation

Inventor: Albert W. Hull 1918 at General Electric Res. Lab

I = IPE - I SE

Anode material
Cu-Be(O): SE-emitter
Layout of the THz IR radiation source with Dynatron Oscillator

Two free beam micro-triodes are controlled by the oscillator voltage, but with by C12 reversed voltage with opposite phase and beam direction. They emit electron pulses as THz emitters inside a resonator. The IR radiation emitter aperture matches the travel of the electron pulse, which is accelerated in ½ period of the oscillator voltage.

Fabrication by lithography and EBID with 0D-material (HaWilKo Patent 2010).

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Characteristics for IR-sources in the 0.2 to 10 THz range

Stability requirements of electrostatic elements limits the usable voltage in miniaturized beam sources.

Experimentally 100 V can be used with metal line distances as small as 1 µm.

Electrons reach by acceleration to 100 V a speed of 6 µm / psec.

The oscillator voltage cuts the DC beam in charge pulses of half a wavelength in length, which corresponds to half the time span of a period.

For example: at 500 GHz the pulse length is 1 psec.

To clearly separate the two electric fields, each beam must pass an aperture of 6 µm diameter located in the center of the resonator through which the electric and the magnetic field of the Hertz Dipole radiation is delivered into the resonator having a dimension of half a wavelength, which is 300 µm at 500 GHz.

<table>
<thead>
<tr>
<th>Frequency THz</th>
<th>Wavelength µm</th>
<th>Resonator E0 µm</th>
<th>1 Electron pulse at 300 V travels µm = IR window µm</th>
<th>S/N at 1 mA DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>1500</td>
<td>750</td>
<td>45</td>
<td>173</td>
</tr>
<tr>
<td>0.5</td>
<td>600</td>
<td>300</td>
<td>18</td>
<td>77.5</td>
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<tr>
<td>1</td>
<td>300</td>
<td>150</td>
<td>9</td>
<td>54</td>
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<tr>
<td>5</td>
<td>60</td>
<td>30</td>
<td>1.8</td>
<td>24.6</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>15</td>
<td>0.9</td>
<td>17</td>
</tr>
</tbody>
</table>
Room-Temperature EBID NGM THz detector

Electrons are excited by THz radiation into unoccupied energy level and move by hopping in an applied E-field, which can be generated by a contact potential difference of the metal lines.

![Diagram of THz radiation and electron motion](image)

**Glass substrate**

**Metal lines**

**NGM Material**

$\Delta E = 60$ meV (Au/C)

$\Delta E = 120$ meV (Pt/C)

low voltage for electron motion

**Only 60 meV are needed for the excitation of one electron**

**Solar Cell Patent by HaWilKo**

Schematic of a HARP detector

In the Be Harp membrane the x-ray photons form electron-hole pairs, and get amplified by the avalanche effect in the HARP membrane.

Adding a first absorber layer from NGM material, and a thin oxide layer to accelerate the photoelectrons from the NGM into the Be a higher number of electrons can be amplified in number by the avalanche effect in the HARP Membrane.

The Spindt type field emitters can be replaced by higher brightness NGM Fe-tips with in plane extractor grid avoiding the disastrous burn out of emitter cells, which kill Spindt-Type emitters.

High-Resolution Koops-GranMat® Field-Emission X-Ray Imager: Photon Counting and Energy Detection

The Field-Emission X-Ray Imager Concept

Photon conversion to Bosons which decay in the high field at the tip and release electrons

Pt/C or Au/C layer with deposited field emitter tips

Acceleration area

Pixel readout at best fabricated with Koops-GranMat®
Deposition with electron beam shadow projection through a stencil mask

Deposition in electron-beam shadow projector

Deposition of Ruthenium from $\text{Ru}_3(\text{CO})_6$

63 min, 0.8 mA/cm², 40 keV
94 nm thick >20000 e / molecule
Reducing Image Projection with variable demagnification

Magnification is set with K2
Focusing and distortion compensation is achieved with K1 and Objective lens excitation.

Multibeam-writing by projection of a regular grid stencil mask and full-field beam movement during exposure.

CTEM magnification of grid patterns and line gratings recorded in collodion film fabricated with the reducing image projection system having a variable reduction factor, top 1:23, bottom 1:110.
Reducing Image Projection printing with deposition

Employing a „Deposition supply“ at the location of the standard anticontamination device „cold finger“ forming an environmental cell allows to print the demagnified mask image in the specimen plane e.g. on a foil or bulk substrate (Rüb et al: 1989)
20:1 Reducing Image Projection printing with Au deposition

Resolution obtained 25 nm
Conclusions

- Metal nanocrystals with 2–4 nm-diameter packed in a Fullerene matrix are produced by FEBIP from organometallic precursors using slow step deposition and sequential epitaxy.

- Electrical resistance measurements show no line resistance but a contact resistance which depends on the contact area.

- Using an approximation like Bohr’s Atom model around the Pt crystals overlapping surface orbital Eigen-states were found, which overlap to similar states of neighboring crystals and allow a Boson-condensate according to Bose’s and Einstein’s theory.

- This transition of electrons and holes from Fermions to Bosons by (Koops-Pairs) allows to explain the Hyper Giant Conductivity Observed at Room Temperature in Metal/Carbon compound Materials.

- The theory of Remeika renders the temperature for the formation of the Bose - Einstein condensate for Rb: 0.5 µK, 2D Litho: 50 mK and Koops-GranMat®: 300K, as they were observed.

- Koops-GranMat® is capable to revolutionize electronics and photonics.
Acknowledgments

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„Die Phantasie ist wichtiger als das Wissen. Wissen ist beschränkt, Phantasie umspannt die Welt.“
Albert Einstein

„Imagination is more important than knowledge. Knowledge is limited, imagination embraces the world“.
AE

Thank you for your attention
[1] Koops –GranMat ®- Name protection in EU, April 2014
[7] Hans W.P. Koops “"Nano Granular Materials (NGM) material for sheets of high refractive index, for high current density carrying wires, sheets and IR to X-ray electromagnetic radiation sensitive photon detector and process for making the same" EP 12 183 564.9, 7. September 2012