1. Introduction. The discovery of superconductivity in iron-based compounds \cite{1} permits one to consider them as a new (copper-free) class of high-$T_c$ superconductors. Indeed, there are some difference of detailed properties of concrete compounds due to features of their band structure, but they exhibit a number of another properties which bring them together with cuprates, for example, layered structure, transition to a class of superconductors under doping of parent, nonsuperconducting compounds etc. (for review, see \cite{2,3}). However, in spite of a large number of works appearing since discovery of new iron-based superconductors ($\sim$ 100 papers per month that is of course less than, but compared with, speed of appearance of publications on the study of properties of cuprates: $\sim$ 400 papers per month, in first ten years after their discovery (see, e.g., \cite{4}), mechanism of superconductivity in new iron-based superconductors (as well as in cuprates) remains to be unclear (cf. \cite{2,3}). In this work, there are presented the evidences indicating that reaching of high temperature for superconducting transition in cuprates in 1986/87 (and in iron-based compounds in 2008) appears to be demonstration of successful realization of the old idea by W.A.Little \cite{5} and V.L.Ginzburg \cite{6} on synthesis of high-temperature superconductors with exciton mechanism of attraction between conduction electrons. Moreover, the picture obtained evidences also that this mechanism is first realized effectively, just as it was predicted by Ginzburg (see, e.g. \cite{2,3,6}), in inhomogeneous system consisting of three layers (HTSC-sandwich): insulator-metal-insulator (which is presented in these compounds in planar form), when conduction electrons (mobile charge carriers) in metallic spacer of sandwich are paired near the Fermi surface due to interaction with excitons in outer insulating plates at temperature which exceeds significantly the phonon limit ($T_{b}^{ph} \leq 40$ K, for details, see, e.g., \cite{7,8,9}).

2. Exciton mechanism of high-$T_c$ superconductivity: the sandwich-like systems. As known, in exciton mechanism of HTSC, proposed in pioneer works by Little \cite{5} and Ginzburg \cite{6} to increase critical temperature of superconducting transition $T_c$, the exchange of conduction electrons by virtual phonons at Cooper pairing is replaced to exchange by virtual excitons which characteristic energy $\hbar \omega_{ex}$ is essentially higher than Debye one $\hbar \omega_D$, characteristic for phonon mechanism. The considered mechanism is performed in frames of BCS model in which the critical temperature is determined as (see, e.g. \cite{6})

$$ T_c = \Theta exp(-1/g). $$

where $\Theta \approx \Theta_{ex} = \hbar \omega_{ex}/k_B$ is the characteristic temperature of the excitons, $\omega_{ex}$ is the characteristic frequency of excitons, $g = N(\varepsilon_F)V$ is the effective constant of interaction, $N(\varepsilon_F)$ is the density of electronic states at the Fermi level $\varepsilon_F$ in the normal state, $V$ is the matrix element of interaction. As it was demonstrated in \cite{6,7,8}, the following set of parameters is optimal to obtain high-temperature superconductivity on the basis of the exciton mechanism

$$ \Theta_{ex} = \hbar \omega_{ex}/k_B \sim 10^3 \div 10^4 K $$

$$ g = g_{ex} \geq 1/5 \div 1/3 $$

Further, in works by Ginzburg (see, e.g. \cite{7,8,9}), it was concluded that because of strong excitonic damping in usual three dimensional (3D) metals, the using of inhomogeneous systems: one dimensional (1D) (see \cite{5}) or two dimensional (2D) \cite{8,9,10}, is most effective for realization of exciton mechanism. The preference of 2D-systems is, in particular, in smaller level of fluctuations as compared with 1D case. From results of analysis (see monograph \cite{9} and references therein) it followed that 3-layer (sandwich-like) system: insulator-metal-insulator (I/M/I) (Fig.1a) is optimal system for realization of such mechanism.
The insulating media of outer plates of sandwich should exhibit clearly pronounced excitonic properties. As follows from theoretical estimations \cite{5,6} (see, also \cite{10}) for effective interaction of conduction electrons in metallic spacer of sandwich with excitons in its outer insulating plates, it is necessary that metallic spacer width \( d \) should be of the order of \( d \sim 10^{-2} \text{ nm} \).

This idea of possibility to obtain the HTSC due to exciton mechanism with its realization, in particular, in layered materials was undoubtedly supported in a number of works on the study of properties of HTSC cuprates in the first year after their discovery (see, e.g., \cite{11}). However, first conclusions on exciton mechanism of HTSC in cuprates appears to be doubted since for measurements there were available mainly polycrystalline samples of cuprates. Theoretical works appeared in the same year as well as later also contained some discrepancies, up to the total negative conclusion relative to observability of increase in \( T_c \) due to exciton mechanism in sandwich-like structures because of relative smallness of this increase in their estimations (see, e.g. \cite{12}). So, 'the question on the role of exciton meccanism in known HTSC seems to be still quite unclear' \cite{3,4}.

3. Planar ‘sandwich’ in conducting planes of HTSC cuprates ( and new iron-based superconductors \((T \approx T^*)\)). In spite of negative result of search for exciton mechanism due to layered structure in cuprates there are evidences indicating that in cuprates it is formed another inhomogeneous \( I/M/I \)-like structure, realizing exciton mechanism in these compounds. It is stripe structure (see, e.g. \cite{13}) appearing in the \( CuO_2 \)-plane in normal state (at \( T < T^* \approx 140 \pm 200 \text{ K} \), depending on compound), when the system enters the pseudogap regime (see below). This structure consists of the system of periodically alternating parallel semi-insulating (spin) and conducting (charge) stripes: \( I/M/I/M/I \)-structure (see, Fig.1b). In conducting stripes density of mobile charge carriers is relatively high - ’metal’ while in semi-insulating ones it is low - ’insulator’. In optimally doped cuprates, conducting stripes (’metal’) have their width near \( d_M \approx 15 \text{ Å} \), and the width of semi-insulating stripes (’insulator’) is near \( d_I \approx 10 \text{ Å} \) \cite{13}. So, this stripe structure can be considered as a series of in-plane \( I/M/I/M/I \)-sandwiches in which it is naturally realized spatial segregation of regions of conductivity and insulating (semi-insulating) ones.

The feature of in-plane sandwich in this structure is that insulating stripes-’plates’ are magnetic in nature. As known, parent (undoped) cuprate compounds are antiferromagnetic (AF) insulators with Neel temperature \( T_N \sim 300 - 500 \text{ K} \) (depending on compound), with ordering type of commensurate spin density wave (SDW) - doubling of period (see, e.g. \cite{2}). In doped cuprates, the decreasing of temperature results (in contrast to static, homogeneous AF-insulating ordering in \( CuO_2 \)-plane in undoped ones) in periodically modulated magnetic structure (see, e.g. \cite{14}) arising at \( T < T^* < T_N \) in this plane. This structure, dynamical, in general case, consists of a sequence of semi-insulating AF-domains (spin stripes) and domain walls which are a well conducting regions (charge stripes) forming due to bunching of excess mobile charge carriers coming to basic \( CuO_2 \)-plane in result of doping process. So formed AF structure appears to be energetically more stable for given system at \( T < T^* \). The magnetic structure within these insulating domains (stripes) are almost antiferromagnetic (length of arrows inside these stripes in Fig.1b corresponds to the magnitude of local magnetization), and adjacent AF insulating domains (stripes) are in antiphase to one another \cite{15}. Note that, according to these calculations, the system of stripes in conducting planes of these compounds can be realized at \( T < T^* \) not only in the form of vertical (or horizontal) sequence of alternating ’metallic’ and ’insulating’ stripes but in diagonal form as well as in the form of crossing stripes when symmetry of the system is unchanged (cf. with \cite{16}), however, all effects characteristic for HTSC-sandwich with vertical stripes (Fig.1b) are here persisted. So, as a basis for such sub-lattice of quantum stripes \cite{13}, 5-layer sandwich: \( I/M/I/M/I \) should be considered rather than 3-layer one: \( I/M/I \) as in Fig.1a.

The second feature of in-plane sandwich in given materials is its dynamical character: as it was obtained already in first works on the study of HTSC cuprates (see, e.g. \cite{13,15}), stripe structure is in general case slowly fluctuating, with characteristic time of the order of \( 10^{-12} \text{ sec} \). However, since time of interaction of conduction electrons (mobile charge carriers) with excitons (see \cite{2}) is much less than characteristic time of fluctuations of spin density then process of this interaction can be considered as instant, i.e. it is realized quasistatic regime what permits use, in adiabatic approximation, for sandwich-like structures theoretical estimations obtained before for static case (see, e.g. \cite{5}). As for new iron-based superconductors, then in-plane ‘sandwich’ in conducting planes should be formed in them by charge stripes enriched with mobile charge carriers during doping (’metal’) alternating with spin stripes with decreased density of mobile charge carriers (AF domains-’plates’). Though ’plates’ of in-plane ‘sandwich’ in this case are not certainly insulating, but rather semi-metallic ones, such possibility of sandwich with semi-metallic, AF-ordered plates is also allowed by Ginzburg model of sandwich \cite{7}.

4. Planar sandwich in \( CuO_2 \)- and (FeAs-) planes as SDW/CW system. As it was noted above, stripe structure in \( CuO_2 \)-plane of HTSC...
cuprates appears in the normal state when in electron energy spectra of the system it is formed the so called pseudogap which persists in superconducting state also ($T < T_c < T^*$), down to lowest temperatures. Such a picture is characteristic for system with ‘interference’ of dielectric and superconducting pairing in which with decreasing temperature first at the part of the Fermi surface it is opened a dielectric gap $\Sigma$ due to electron-hole (e-h) pairing and only at lower temperature the superconducting gap $\Delta$ is formed due to (e-e) pairing (see, [3, 10]). In particular, such behaviour is characteristic for systems of itinerant electrons with interplay of superconductivity and magnetism [13, 20]. In such systems dielectric transition occurring in the normal state at $T < T^*$ is realized in the form of transition of the system from spin-disordered state to the AF SDW state when at symmetric parts of the Fermi surface it is formed SDW-dielectric gap (pseudogap) with magnitude $\Sigma_{SDW}$ and only at lower temperature $T_c < T^*$ it occurs a superconducting transition (it is opened a superconducting gap $\Delta_{SC}$) so that at $T < T_c$ two order parameters (SDW + SC) coexist with one other in the system [13, 21]. In other words, from here it follows that in such system superconducting transition is preceded by magnetic (AF SDW) phase transition ($T_c < T^*$). Indirect evidence for such (AF SDW) transition in cuprates was obtained by us before, on the basis of detailed analysis of in-plane resistive measurements in magnetic field ($\vec{H}\parallel\vec{e}_x$) [22], and recently, from detailed measurements of elastic scattering of polarized neutrons [18], it was obtained a direct evidence for such magnetic transition in pseudogap regime for a number of HTSC cuprate compounds.

In new iron-based superconductors, as it was already indicated from the first measurements at polycrystals (see, e.g., [23]) it should be observed the same picture [14]. So, practically just it becomes known that in undoped iron-based compounds (semi-metal), as in cuprates, it was fixed (and have been studied in details, in both resistive and neutron measurements (see, [2, 17]), a transition to AF SDW state commensurate with lattice, with Neel temperature $T_N \approx 140$ K but with partial (in contrast to total one in undoped cuprates) SDW-dielectricization of the spectra. (Here, it is necessary to note that the problem of phase transition metal-insulator, with dielectricity of the electron energy spectra, was solved in well-known work [24] just for the case of semi-metal). And indeed, in spite of more complex band structure in iron-based compounds (as compared with the case of cuprates) (see, e.g., [2]), in normal state of these compounds, also at $T \leq T^*$ it is observed pseudogap in electron energy spectra (cf. [17, 22]) (which, obviously can have more complex structure or to be a system of pseudogaps), persisting also in superconducting state ($T < T_c < T^*$). In addition, in literature (see, e.g., [2, 17]) there are a number of evidences indicating to SDW nature of the pseudogap observed in new iron-based superconductors although direct observations of quasistatic, in general case, magnetic (SDW) order in doped compounds are absent at present (see, however, recent work [47]) (in cuprates, indirect (resistive) evidence for magnetic (AF SDW) phase transition, preceding SC one, was obtained in [22] while direct (neutron) ones only recently in [18], see above).

Since SDW-period in conducting planes of HTSC-cuprates (and new iron-based superconductors) is (in contrast to undoped (parent) systems) incommensurate with crystal lattice period, then formation of SDW is accompanied by generation in these planes of charge density wave (CDW) with one-half wavelength $\lambda_{CDW} = \lambda_{SDW}/2$ [14, 27] and thus lattice deformation wave. As it’s seen from Fig.1b, period of the SDW formed by spin stripes (arrows), because of antiphaseness of adjacent domain stripes appears to be in two times larger than period of the CDW formed by equivalent to one another charge stripes (circles) (see, e.g., [28]). This fact indicates again (see, Sec.3) that as in-plane sandwich in these systems it should be taken a structure with 5 stripes I/M/I/M/I (Fig.1b) rather than with 3 elements (I/M/I) as in the case of nonmagnetic insulating plates (Fig.1a).

5. The character of excitons in HTSC-cuprates (and new iron-based superconductors). The exciton characteristics in AF semi-insulating stripes-’plates’ of planar sandwich in CuO$_2$-plane of HTSC-cuprates (see, Fig.1b) are in fact determined by excitonic spectrum of AF-insulating CuO$_2$-plane in parent (undoped) compounds (e.g. La$_2$CuO$_4$ and YBa$_2$Cu$_3$O$_6$). This proposal is connected with fact that, as it was noted above (see Sec.3), these AF semi-insulating stripes-’plates’ of planar sandwich in CuO$_2$-plane appear at $T < T^* < T_N$ in doped compounds in fact as a consequence of ‘dicretization’ of initially homogeneous AF-insulating state of CuO$_2$-plane (characteristic for undoped compounds of cuprates) to the system of insulating antiphase spin stripes-domains separated by charge stripes (domain walls) formed by excess mobile charge carriers coming to CuO$_2$-plane under doping process.

As it was observed already in first measurements of optical absorption at single crystals of cuprates (see, e.g., [29]), in dielectric region of phase ($T, x$)-diagram, in spectra, at long-wave side of low-energy ($\varepsilon = \hbar \omega < 3$ eV) absorption edge, in the energy range around 1.5 eV, there were observed features characteristic for excitonic absorption. Moreover, these features appeared only at polarization of the electric field in the incident wave in plane of CuO$_2$-layers ($\vec{E}||ab$) which fact indicates to planar character of excitons in cuprates
(at polarization of electric field in the incident wave normally to the plane of CuO$_2$-layers ($\vec{E} \perp |\vec{c}|$) such features in spectrum were absent) (the discussion on properties of same 2D-excitons and anisotropy of optical absorption in crystals see, e.g. in [30]).

This absorption edge is provided, (see, e.g. [29]), by interband transition with charge transfer (CT-transition): $O2p \rightarrow Cu\ 3d_{x^2-y^2}$ in CuO$_2$-plane, with width of optical energy gap $\Delta_{CT} \approx 1.5$ eV, so that corresponding excitons in CuO$_2$-plane relate to the class of charge transfer excitons (CT-excitons) (cf., [31, 32]). Such CT-excitons are formed in CuO$_2$-plane in result of CT-transition between two subsystems in this plane, one of which is formed by square plaquette consisting of 4 O atoms in square vertices and Cu atom in the centre of this square, and as another subsystem it is considered Cu atom from adjacent plaquette to which the electron from nearest to it O atom comes (for details, see e.g. [33]). In energy region to this process it corresponds interband transition from filled $O2p$-band to empty $Cu\ 3d$-band. In result, both Cu cites appear to be spinless and then so-formed CT-excitons move across lattice in CuO$_2$-plane coherently, without disturbance of basic AF matrix of this plane (cf. [31]) in contrast to single electron or hole, movement of which in CuO$_2$-plane appears to be incoherent leading to their localization [33].

Experimentally, the mobility (delocalization) of CT-excitons in CuO$_2$-plane of these materials was established only recently, from measurements of high resolution resonant inelastic x-ray scattering (%(RIXS)) at single crystals of parent, undoped AF insulating compound La$_2$CuO$_4$ [55]. Here, it is necessary to note that possibility of using of inelastic x-ray scattering to study the excitons of 'electronic' type, slightly connected with lattice vibrations, was discussed in the work by Agranovich and Ginzburg [30] (see, also [30]), for 45 years before the work [35]. Moreover, obtained in [31, 36] estimations of typical value of energy for 'electronic' exciton ($h\omega \geq 1$ eV), width of corresponding band ($h\Delta\omega \geq 0.5$ eV) and even resolution of X-ray spectrum apparatus ($\sim 0.3$ eV) in fact coincide (!) with those for CT-excitons obtained in work [35]: energy $h\omega \leq 1.5$ eV, band width $\sim 0.5$ eV and ‘high resolution of apparatus’ (synchrotron) $\sim 300$ meV.

This study demonstrates that CT-excitons in CuO$_2$-plane are mobile quasiparticles with quadratic dispersion (in contrast to the case of localized excitons in other isostructural compounds (e.g. La$_2$NiO$_4$)). In addition, the whole mass of CT-exciton $M = m^*_e + m^*_h$, determining its motion as a whole is equal, according to estimation in Wannier-Mott exciton model, $M = 3.5 m_e$, that also is in agreement with estimations used before [32]. Here, $m_e$ is the mass of the free electron, $m^*_e$ and $m^*_h$ are, respectively, effective masses of quasiparticle and quasihole forming an exciton.

6. The effective parameters of a BCS model for planar CT-excitons in HTSC-cuprates(610,561),(937,897) and (new iron-based superconductors). So, as follows from these experiments, in material of insulating ‘plates’-stripes of planar sandwich in CuO$_2$-plane which, in fact, are result of ‘discretization’ of uniformly AF-ordered insulating CuO$_2$-plane (characteristic for undoped compounds) (see, above, Sec.3) can propagate CT-excitons with characteristic energy $h\omega \leq 1.5$ eV, providing the possibility for superconducting pairing of conduction electrons (mobile charge carriers) in ‘metallic’ spacer of sandwich at higher $T_c$ due to exchange by these CT-excitons. The characteristic temperature $\Theta_{ex}$, corresponding to this energy, is of the order of $\sim 10000 - 15000$ K, that is in agreement with estimations for this mechanism, see (2). Such agreement permits estimate effective parameter $g$, determining the measure of attraction of conduction electrons (mobile charge carriers) in ‘metallic’ spacer. From expression (1) for critical temperature $T_c$ it follows that $g \sim 1/\ln(\Theta_{ex}/T_c)$, and, for example, for maximum critical temperature $T_c^{max} \approx 90$ K in optimally doped YBa$_2$Cu$_3$O$_{7-\delta}$ we have: $g \sim 0.2$. Analogously, for La$_{2-x}$Sr$_x$CuO$_4$ ($T_c^{max} \approx 40$ K), $g \sim 0.18$.

Further, in undoped iron-based compounds, as follows from recent measurements of optical absorption at single crystals (see, e.g. [37, 38]), features (under conditions of finite conductivity of these compounds) characteristic for excitonic absorption in lightly doped cuprates were observed in spectrum at energy $\hbar\omega \sim 0.65$ eV, and, as in cuprates, at long-wave side of absorption edge, which can correspond (in analogy with cuprates) to CT-transition (cf. with [35]) in conducting planes of these compounds. This energy corresponds to characteristic temperature of excitons of the order of $\Theta_{ex} \sim 7000$ K, what, at maximum reached $T_c^{max} \approx 55$ K, leads to the value of interaction constant also of the order $g \sim 0.2$.

Since, in real HTSC single crystals, even at exciton mechanism, it is necessary to take into account the interaction of conduction electrons (mobile charge carriers) with phonons (cf. [10]), then obtained above magnitudes of effective parameter $g \sim 0.2$, which are in agreement on the order of magnitude with calculated magnitudes for electron-phonon interaction in cuprates (see, e.g., [41]), and in new iron-based superconductors (see, e.g., [42]), indicate to moderate force of both electron-phonon and electron-exciton interactions in both classes of these compounds. Thus, correlation of magnitudes of effective parameters $\Theta$ and $g$ in BCS model (1) obtained for both classes of compounds (see, also (2)) denotes in fact that high values of critical temperature of superconducting transition in these compounds are provided by combination of both parameters in (1):

$$T_c^{max} \approx 55 \text{ K}, \quad g \approx 0.18.$$
sharp rise of pre-exponential factor $\Theta$ due to mobile, planar CT-excitons and increase of density of states in exponent index $g$, due to partial SDW-dielectrication of electron energy spectra (accompanied by formation of in-plane sandwich in conducting planes) in the normal state.

It is interesting that in fact to the same conclusion that high critical temperature of superconducting transition in cuprates is a result of combination of contributions from excitons and moderate phonon mechanism came and author of pioneer work [5] Little with coauthors [43]. In this recent work, with using of precious measurements of optical absorption in thin crystalline films of Tl$_2$Ba$_2$CaCu$_2$O$_{8+x}$ it was studied frequency dependence of relation of magnitudes of optical conductivity in superconducting $\sigma_e$ and normal $\sigma_n(T \geq T_c)$ states: $\Re[\sigma_e(\omega)/\sigma_n(\omega)]$. At experimental curve there was observed a declination from known calculated dependence in frames of the BCS theory [44], in particular, at energy $\hbar\omega \approx 1.2$ and 1.7 eV, which with taking into account measured RIXS-spectra (cf. with above [30, 35, 36]) were treated as exciton peaks, corresponding to electronic excitations in the copper subsystem (cf., however [29]). The characteristic temperatures corresponding to obtained energies are in agreement on the order of magnitude ($\Theta_{xx} \sim 10^4 K$), with both obtained above corresponding temperatures in CuO$_2$-planes of LSCO and YBCO and with (2). And value of $T_c \approx 105K$ for their films results also in $g \sim 0.2$.

7. The onset temperature of superconducting transition ($T^{onset}_c$) at exciton mechanism in cuprates (and new iron-based superconductors). Though, principal scheme of manifestation of the Little-Ginzburg exciton mechanism in doped compounds of cuprates (and new iron-based superconductors) are already above described, however, in real systems there is exists a number of features caused by additional factors determining behaviour of the system of mobile charge carriers in the normal state and decreasing thus real temperature of superconducting transition in the system. So, for example, it is necessary to take into account role of fluctuations of magnetic (SDW) order parameter (amplitude spin fluctuations of local spin density) characteristic for magnetic systems of itinerant electrons (see, e.g. [21]) which gives rise, in particular, to additional (to phonon one $\rho_{ph}(T)$) contribution $\rho_m(T)$ to the total resistivity $\rho_{tot}(T) (\rho_{tot}(T) = \rho_{ph}(T)) + \rho_m(T)$, usual approach for magnetic metals, see, e.g. [28]). This contribution $\rho_m(T)$ to resistivity disappears (characteristic time of fluctuations of spin subsystem is noticeably larger than characteristic time of electronic processes) at temperatures determined by parameters of real system.

Experimentally, onset temperature of superconducting transition $T^{onset}_c$ for concrete HTSC single crystal can be determined from point of intersection of temperature dependence of in-plane resistivity $\rho(T)$ with well known universal Gruneisen-Bloch curve determining temperature dependence of phonon contribution in resistivity $\rho_{ph}(T)$ in most metals [43] (for more details, see [17, 22]). At this temperature, the behaviour of the system of mobile charge carriers in ‘metallic’ spacer (M) of in-plane sandwich begins to be determined (without taking into account the influence of its ‘insulating’ plates (I)) only by interaction with phonons, which, however, as follows from expression (1), appears to be not so strong for Cooper pairing of mobile charge carriers at given temperature, even under conditions of increased density of states at the ends of SDW-dielectric gap (pseudogap) at the Fermi surface $(T < T^*)$ [16, 21]. Because of this, ‘insulating’ plates (I) of in-plane sandwich play here a crucial role - it is turned on the interaction of mobile charge carriers in ‘metallic’ spacer (M) of in-plane sandwich with CT-excitons in its ‘insulating’ plates (I) (with essentially wider region of energy for interaction near the Fermi surface than only at phonon mechanism) leading to their effective Cooper pairing and transition of the system to superconducting state at given (unreally high for only phonon mechanism) temperature.

Then, as follows from above, excitons (‘polarization waves’ [6, 7, 30]) from insulating stripe-plate of in-plane sandwich (Fig.1b) can interact with mobile charge carriers in its ‘metallic’ stripe-spacer, even from two sides, providing thus additional mutual interaction of mobile charge carriers due to exchange by mobile, planar CT-excitons giving rise to formation of Cooper pairs and superconducting transition at temperature significantly higher than phonon limit $(T^{ph}_c \leq 40 K$, see, e.g. [9]). On the other hand, it is necessary also note that in the systems under consideration, since width of ‘insulating’ plates (I) of in-plane sandwich satisfies the conditions for Josephson tunneling, mobile charge carriers from adjacent ‘metallic’ spacers (M) are able to form a Cooper pairs (due to exchange by mobile, planar CT-excitons from ‘insulating’ plates (I) between them) what is consistent with the fact that e.g. in YBCO-system the distance between ‘metallic’ spacers (M) in planar sandwich - CDW wavelength ($\lambda_{CDW}$), is equal to coherence length in CuO$_2$-plane ($\xi_{ab}$): $\xi_{ab} \approx \lambda_{CDW} \approx 25 Å$ [22, 23]. So, adjacent AF ordered ‘insulating’ plates-domains (I) of in-plane sandwich, because of their antiphase can provide additional stabilization of the system (at given (high) temperature) due to co-phasing of spins of mobile charge carriers in its adjacent equivalent ‘metallic’ spacers (M) (domain walls).

Of course, presented here picture is schematic enough and needs in further development however, it, at least, permits describe from unified viewpoint...
so-called ‘anomalous’ behavior of these superconductors and obtain self-consistent, quantitative estimations of critical parameters \([22, 28]\). It also indicates possible ways of increasing of critical temperature (RTSC) in similar, layered AF-ordered compounds with CT-transition in plane of layers as well as in conducting, artificial inhomogeneous sandwich-like systems, where insulating material of plates is AF-ordered \([10]\), what permits to hope for further increase of critical temperature in such compounds in near future.

8. Possibility of creation of new artificial HTSC (RTSC) superlattices with AF-insulating layers. The picture of stripes in CuO₂-planes of HTSC and determination of their widths \([13]\) led in beginning of 90th to attempts to reconstruct such stripe structure with critical temperature \(T_c \sim 300 \text{ K} \) (RTSC) artificially, on the basis of metallic structure at the atomic limit (see \([18]\)), which can be realized with using of molecular beam epitaxy, evaporation, lithography, chemical sintering, electrochemical deposition etc. Such superconducting heterostructure is formed by superlattice of quantum elements (wires by thickness \(\sim 10 \text{ Å} \) of one material (metal) incorporated between another ones (insulator), which provides periodic potential barrier for electrons in first one.

However, in this picture the insulating elements of such superlattice are considered only as creating periodic potential for metallic elements without taking into account their magnetic nature. Of course, from viewpoint of exciton mechanism such structure (in 2D version) can be considered as planar ‘sandwich’ but only as 3-layer I/M/I heterostructure (see Fig.1a). The taking into account the magnetic nature of ‘insulating’ stripes permits propose a number of new ways to model HTSC cuprates. Most direct of them is creation of artificial magnetic (insulating) stripes in planes parallel to conducting planes of HTSC or (and) AF-insulating layers with corresponding metallic ones realizing SDW/CDW structure with charge and AF-insulating stripes in cross-section, see Fig.1c.

The works of such type on HTSC, at present time, as known, are performed. First, it is necessary to note experiments with atomically plane thin HTSC films and heterostructures (multilayered structures, superlattices) \([49]\). For these experiments, with using of molecular beam epitaxy there were created cuprate HTSC-heterostructures with atomically smooth surfaces and interfaces. Further, in the process of growth of structure, in real-time regime, with using of special precious apparatus it was controlled the crystal structure of the surface, chemical composition of surface layers etc. what permitted directly correct a technological regime. There were studied the effects of contact of thin layers of HTSC cuprates with different level of doping (undoped, underdoped, optimally doped, overdoped). In particular, it was obtained superconductivity with high \(T_c\) at the boundary of double layers consisting of two non-superconducting (overdoped and underdoped) cuprates (LSCO).

To the same class of experiments, obviously, can be related also that in \([54]\), where film of LSCO, with width \(\sim 150 \text{ Å} \) was grown with using of molecular epitaxy at SrLaAlO₄ substrate which lattice period was slightly different from lattice period of the film grown. Incommensurateness of lattices led to twofold increase of \(T_c\) as compared with bulk sample. Increase of \(T_c\) in these cases can be caused by secondary effect (see above, Sec.4) namely, creation of lattice deformation wave in the sample of HTSC cuprate at given temperature which can lead to generation of CDW and hence SDW in conducting planes (formation of stripe structure (a series of in-plane sandwiches)) and thus to both increase of density of states at the Fermi surface and appearance of conditions for effective interaction of mobile charge carriers in ‘metallic’ stripes and mobile CT-excitons in ‘insulating’ stripes, and, hence, to superconducting transition at higher temperature due to combination of these two factors.

In general case, for creation of artificial sandwich-like structures with AF-insulating layers-plates (see Fig.1c and \([46]\)) it can be used a technology of layer-by-layer evaporation of alternating layers metal/insulator: such methods with evaporation of layers with width \(\sim 10 \text{ Å} \) are used at production of x-ray mirrors (see, e.g. \([51]\)), structures with giant magnetoresistance (see, e.g. \([52]\)), and namely superconducting heterostructures metal/semiconductor \([53]\).

9. Conclusion. So, performed analysis demonstrates that in both cuprates and new iron-based superconductors there are satisfied all conditions of Ginzburg, optimal for realization of exciton mechanism in HTSC-sandwich (Fig.1) which were formulated by him in the end of 60th \([7]\):

\[
d \sim 10 - 30 \text{ Å}, \quad n \sim 10^{18} - 10^{23} \text{ cm}^{-3}, \quad \hbar \omega_{ex} \sim 0.3 - 3 \text{ eV}, \quad \hbar \Delta \omega \sim 0.1 - 3 \text{ eV}.
\]

Moreover, appearance of high-temperature (middle-temperature) superconductivity already in second class of layered AF systems with transition of parent (undoped) system to commensurate SDW state with total (cuprates) or partial (iron-based compounds) SDW-dielectricization of electron energy spectrum and appearance in the system of mobile, planar CT-excitons is important in search for HTSC and RTSC in such systems which can be at present considered as most promising. The key moment in such search can be study of layered systems of transition metals with high value of energy of CT-transition in plane of layers which in parent (undoped) state are instable relative to transition to the state with
commensurate CDW when in the system it occurs a total (CT-insulator) or partial (CT-semi-metal) SDW-dielectricization of electron energy spectra. The search for such compounds obviously should be performed with using of measurements of optical absorption at single crystals, at polarization of electric vector in incident wave parallel to layers ($\vec{E} \parallel [ab]$). After selection of promising compounds it can be realized their doping to perform the test for superconductivity with using of measurements of susceptibility or resistivity at $T \lesssim 300$ K. Since materials of such type are well known enough and after discovery of new iron-based superconductors, the investigation on search for similar compounds is coming intensively, then, in principle, it is possible to wait an appearance of RTSC in them in near future.

The author is thankful to V.L. Ginzburg for a critical reading of the work.

[1] Kamihara Y. et al. J. Am. Chem. Soc. 130 3296 (2008)
[2] Ishida K. et al. J. Phys. Soc. Jpn. 78 062001 (2009).
[3] Ginzburg V.L. On Superconductivity and Superfluidity (Springer-Verlag, Berlin, 2009).
[4] Ginzburg V.L. Usp. Fiz. Nauk 174 1240 (2004)
[5] Little W A Phys. Rev. 134 A1416 (1964)
[6] Ginzburg V.L. Zh. Exp. Teor. Fiz. 47 2318 (1964); Phys. Lett. 13 101 (1964)
[7] Ginzburg V.L. Usp. Fiz. Nauk 95 91 (1968); 101 185 (1970)
[8] Ginzburg V.L. Usp. Fiz. Nauk 118 315 (1976)
[9] Problem of High Temperature Superconductivity (Eds. V.L. Ginzburg and D.A. Kirzhnitz, Nauka Press, Moscow, 1977) [New York: Consultants Bureau, 1982
[10] Allender D., Bray J., Bardeen J. Phys. Rev. B 7 1020 (1973)
[11] Kamaras K. et al. Phys. Rev. Lett. 59 919 (1987)
[12] Varma C.M., Schmitt-Rink S., Abrahams E. Sol. St. Commun. 62 681 (1987)
[13] Bianconi A. et al. Phys. Rev. Lett. 76 3412 (1996)
[14] Izyumov Yu.A. Usp. Fiz. Nauk 144 439 (1984)
[15] Kato M. et al. J. Phys. Soc. Jap. 59 1047 (1990)
[16] Rusinov A.I. et al. Zh. Exp. Teor. Fiz. 65 1984 (1973)
[17] Mazov L.S. arXiv:0805.4097 (2008)
[18] Fauque B. et al. Phys. Rev. Lett. 96, 197001 (2006)
[19] Machida K. Appl. Phys. A 35 193 (1984)
[20] Moriya E. Spin fluctuations in magnets with itinerant electrons (Springer-Verlag, Berlin, 1985).
[21] Mazov L.S. J. Supercond. Nov. Magn. 20 758 (2008); J. Supercond. 18 713 (2005).
[22] Mazov L.S. Low Temp. Phys. 17 1358 (1991); see, also in Progress in High Temperature Superconductivity, vol.32, (Eds.: A.G.Aronov, A.I. Larkin and V.S. Lutovinov, World Scientific, Singapore) (1992), p.605-610;
[23] Zhi-An Ren et al. arXiv:0803.4213 (2008)
[24] Keldysh L.V., Kopnov Yu.V. Sov. Phys.-Solid State 6 2792 (1964)
[25] Xu Y-M et al. arXiv:0905.4467 (2009)
[26] Chen, H. et al. Europhys. Lett. 85, 17006 (2009).
[27] Kulikov N.I., Tugushev V.V. Usp. Fiz. Nauk 144 643 (1984)
[28] Mazov L S Phys. Rev. B 70 054501 (2004); see, also in Superconductivity Research at the Leading Edge (Ed. P.S. Lewis) (New York: Nova Science Publishers, Inc., 2004) p.1-23
[29] Basov D N, Timusk T Rev. Mod. Phys. 77 721 (2005)
[30] Agranovich V.M., Ginzburg V.L. Crystal Optics with Taking into Account of Spatial Dispersion and the Theory of Excitons (Moscow: Nauka Press, 1965); [Interscience Publishers, New York, 1966]
[31] Sturge M.D. in: Excitons (Eds.: E.I.Rashba and M.D.Sturge) (Moscow: Nauka Press, 1985), p.9 (in Russian)
[32] Knoester I., Agranovich V.M. Thin films and nanostructures 32, 1 (2003)
[33] Wang Y.Y. et al. Phys. Rev. Lett. 77 1809 (1996)
[34] Tanabe Yu., Aoyagi K. in Excitons (Eds.: E.I.Rashba and M.D.Sturge) (Moscow, Nauka Press, 1985), p.424 (in Russian)
[35] Collart E. et al. Phys. Rev. Lett. 96 157004 (2006)
[36] Agranovich V.M., Ginzburg V.L. Zh. Exp. Teor. Fiz. 40 913 (1961)
[37] Boris A.V. et al. arXiv:0806.1732 (2008)
[38] Qazilbash M.M. et al. arXiv:0808.3748 (2008)
[39] Andreev S.S. et al. Phys. Rev. Lett. 101 758 (2008)
[40] Little W.A. et al. Physica C Superconductivity 40 (2007)
[41] Boris A.V. et al. arXiv:0806.1732 (2008)
[42] Qazilbash M.M. et al. arXiv:0808.3748 (2008)
[43] Ziman J.M. Electron and phonons (Oxford at the Clarendon Press, 1960)
FIG. 1: The sketch of HTSC-sandwich-like system.  
a) 3-layer Ginzburg HTSC-sandwich with insulating outer plates and metallic spacer (shaded) between them; d is the thickness of the metallic spacer; two circles in the middle of metallic spacer correspond to conduction electrons which are attracted to one other via exchange by virtual excitons (wavy lines), see, e.g. [7].  
b) 5-layer planar 'HTSC-sandwich' (stripe structure) in the CuO2 plane of cuprates: insulating 'plates' (semi-insulating, spin stripes) are AF-ordered (arrows indicate direction of local magnetization inside the 'plate', the length of arrow corresponds to magnitude of this magnetization, after [15]); 'metallic-spacer' (conducting, charge stripes) regions are shaded, circles in these regions correspond to mobile charge carriers. The 'insulating-plate' and 'metallic-spacer' widths correspond to the cuprates with optimal doping [13]. Note that nearest insulating 'plates' are in antiphase to one other, and the spin density wave (SDW) formed by them as well as accompanying it the charge density wave (CDW) formed by equivalent 'metallic spacers' are incommensurate with the lattice period (see, e.g. [46] and references therein); c) artificial multilayered structure metal/AF-insulator, cross section of which corresponds to in-plane sandwich in Fig.1b.