Vetenskapsrådet

Application

2015-03-31

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Information about application

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Funds applied for

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Descriptive data

Project info

Project title (Swedish)*

Novel Bandgap RF micro-acoustic devices

Project title (English)*

Avancerade bandgap radiofrekvens mikro-akustiska komponenter

Abstract (English)*

Modern telecommunications make extensive use of acoustic waves in solids to process (e.g. filter, delay, compress, etc) RF electromagnetic signals owing to their extremely low losses and low propagation velocity. The latter is about 5 orders of magnitude lower than the speed of the light which results in correspondingly smaller device dimensions compared to the electromagnetic wavelength. Consequently, RF acoustic waves exhibit wavelengths lying in the micron and submicron ranges, which means that these waves can be manipulated by similar in size physical structures. Today's state of the art technologies employ a 1D design topology which limits device performance significantly. This necessitates the development of radically new approaches to meet the requirements of future telecommunications. We propose the use of 2D and eventually 3D periodic bandgap structures which according to our preliminary theoretical studies would result in a leap in performance. Thus, the main objective of the proposed research is the development of a novel family of sub-micrometer periodic surface structures exhibiting hypersonic bandgaps for use in high performance radio frequency (RF) filter and other applications.

Popular scientific description (Swedish)*

Den explosionsartade utvecklingen av mobiltelekommunikation under de senaste 20 åren har förändrat vårt industrisamhälle till ett väldigt avancerat informationsteknologisamhälle. Vår personliga mobiltelefon har blivit en viktig pryl som spelar en central roll i det vardagliga livet. Vi kan konversera med vem som helst när som helst, vi är ständigt uppkopplade mot internet och får nyheter och meddelanden ögonblickligen, vi kan t.o.m. se våra favoritprogram eller filmer genom en knapptryckning medan vi förflyttar oss, etc. Denna utveckling har gått så snabbt att endast ett fåtal av oss har haft möjlighet att begrunda och identifiera de huvudsakliga orsakerna till denna utveckling. Till stor del beror den säkerligen på den lika explosionsartade utvecklingen av mikroelektronik och vår förmåga att göra saker mindre, bättre och billigare. Det är dock relativt okänt att denna utveckling delvis beror på förmågan hos en del kristallina material att generera elektricitet vid mekanisk deformation, vilket är skälet till att de kallas för piezoelektriska material. Namnet är en kombination av två grekiska ord; ”trycka” och ”elektron” i nämnda ordnig. Har du någonsin funderat på varför många personer kan prata samtidigt i sina mobiltelefoner utan att störa varandra? Du kanske känner till att varje telefon använder en unik radiofrekvens. Men hur kan telefonen skilja på de olika frekvenserna? Det är här de piezoelektriska materialen gör underverk. Med hjälp av dessa material har ingenjörer konstruerat speciella elektronikkomponenter, s.k. filter, som separerar de olika radiofrekvenserna med minimal signalförlust. Kvaliteten på dessa filter bestämmer antalet simultana telefonsamtal som varje nätverk kan upprätthålla. Dessa filter avgör också hur länge våra batterier räcker. Kommande generationer mobilnätverk kommer att behöva elektriska filter med extrem prestanda vilket inte kan uppnås med dagens teknik. Denna ansökan syftar till att ge nya insikter och utveckla ny sakkunskap som möjliggör utveckling av filter med extrem prestanda vilket kommer att göra mobila videosamtal lika vanliga som dagens röstsamtal.

Project period

Number of project years*

4

Calculated project time*

2016-01-01 - 2019-12-31

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*

2. Teknik > 202. Elektroteknik och elektronik > 20205. Signalbehandling

2. Teknik > 202. Elektroteknik och elektronik > 20204. Telekommunikation

2. Teknik > 202. Elektroteknik och elektronik > 20299. Annan elektroteknik och elektronik

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Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

Filter

Keyword 2*

bandpass

Keyword 3*

radio frequency

Keyword 4

insertion loss

Keyword 5

Q-factor

Research plan

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

Inga etiska frågor är aktuella i samband med projektet

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

Novel Bandgap RF micro-acoustic devices

1. Purpose and aims

The main objective of this proposal is the development of a novel 2D approach for the design and fabrication of radio-frequency (RF) micro-acoustoelectric devices such as resonators, filters, etc with a radically improved performance and satisfying the requirements of the next generations of wireless communication technologies. The approach proposed is based on the utilization of a specific class of phononic crystals (the acoustic analog of the photonic crystals) proposed recently by the applicants and named as surface phononic gratings (SPG) [1-3]. SPG represent 2D lattices consisting of periodically distributed masses formed on the piezoelectric crystal surface employing the standard planar technology. This approach is expected to result in a radical increase of the quality factor (Q) through the utilization of 2D omnidirectional bandgaps as well as, to a certain extent, of the electromechanical coupling K^2 through a specific redistribution of the energy localization near the crystal surface. Hence, the purpose of the project is to lay both the theoretical and the experimental foundations for the design of critical components for the next generation wireless communication as well as other micro-acoustic based technologies. The specific goals include the development of the theoretical framework of SPG as well as to experimentally demonstrate its advantages through the design, fabrication and characterization of specific devices. The performance is primarily evaluated by the overall losses in the device which are expected to be by about one order of magnitude lower than current state-of-the-art devices which is sufficient to meet requirements for future RF wireless communications. Although the latter are the main focus of the work the results obtained will be equally useful for a wide range of other applications including low noise oscillators, sensors, wireless sensor networks, passive RFIDs etc. In this context, a specific realization of phononic bandgap biosensors will also be demonstrated.

2. Survey of the field

Currently, the mobile market has a significant demand for low insertion loss filters and duplexers with high selectivity and excellent isolation[4]. Reduction of filter losses translates directly into efficient use of bandwidth, higher bitrates, reliable communications, extended battery life, etc. On the other hand, as more communication bands are standardized for national or global use, and the requirements on filter performance are continuously ‘tightened’, the demand for filters with improved out-of-band rejection and steeper skirts is unremitting. The current state-of-the-art RF filter technology is based on the microwave micro-electroacoustic technology due to its small form factor and low fabrication cost while providing unrivaled performance. Most generally, electroacoustic devices (typically resonators) convert the electrical signal into an acoustic wave (and vice versa) employing the piezoelectric effect, and are characterized by their quality factor Q and the coefficient of electromechanical coupling (K^2), the latter representing the ratio between the mechanical and electrical energy in the resonator. The product $Q \times K^2$ is an important figure of merit with respect to subsequent filter design. The higher this product is the better the filter performance in terms of loss, skirt and out-of-band rejection. The electromechanical coupling is to a large extent dependent on the specific combination of piezoelectric material and type of acoustic wave, while the Q factor can vary significantly depending on the resonator topology. Pushing the $Q \times K^2$ product for a specific material-wave combination requires advanced design tools to optimize the losses in the device, while preserving efficiency of excitation. Most generally, major extrinsic loss mechanisms include acoustic leakage due to acoustic wave radiation away from the resonance cavity as well as ohmic losses in the electrodes. Intrinsic material losses are significantly smaller and do not dominate device performance.

The dominating RF filter technology today is the surface acoustic wave (SAW) technology owing to its robustness and design flexibility as well as low cost. The SAW technology employs low loss, single crystalline piezoelectric substrates such as Quartz, $LiTaO_3$ and $LiNbO_3$. The main building elements of a SAW resonator, as illustrated in Fig. 1a, are the **inter-digital transducer** (IDT), the **reflector gratings** (the end gratings in Fig. 1b) and the electrical **busbars**. SAW components have steadily increased their performance in recent years, although the Q factors are still insufficient for achieving sufficiently low loss and steep skirt RF filters. Performance needs a significant boost to meet the requirements of future applications where loss and selectivity are critical.

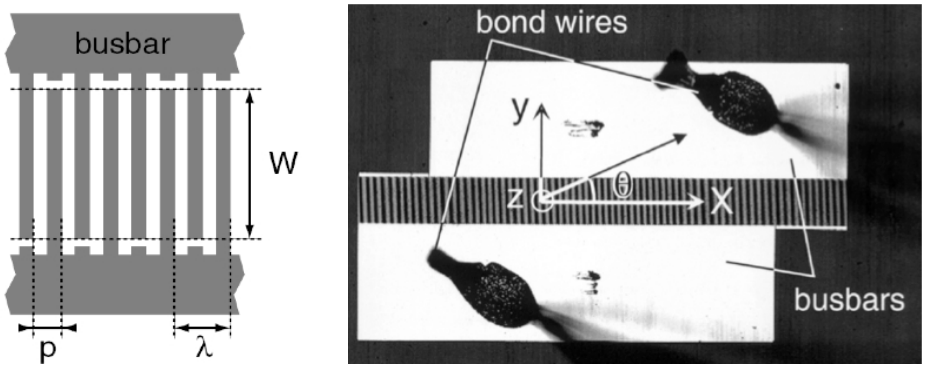

Figure 1 (a) Inter-digital Transducer (b) complete SAW resonator

A closer look at the state-of art in the field indicates that the dominating losses in SAW filters are extrinsic stemming from the 1D design constraints imposed by the use of IDTs. Figure 2 illustrates one major loss mechanism in SAW devices caused by the unavoidable acoustic energy radiation through diffraction, refraction and other wave phenomena[5]. Increased device aperture, as noted below, reduces such losses but results in increased ohmic losses due to increased finger length.

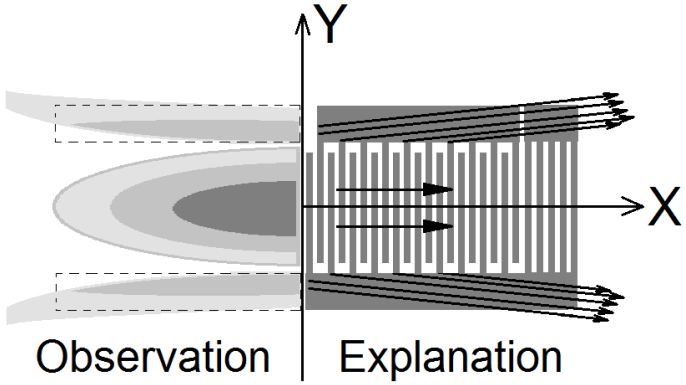

Figure 2. SAW diffraction losses, i.e. acoustic leakage outside the resonating cavity through diffraction [5]

In a classical SAW device the narrow but long fingers of the IDT conduct the electrical current and are accessible from one side only. At a typical metallization ratio of 50% this results in a high electrode resistance and hence in deterioration of device performance. In order to reduce the effect of series resistance a typical SAW transducer must have short fingers which results in an increased IDT length due to impedance requirements. On the other hand, diffractive acoustic leakage (see Fig. 2) occurring from the sides of the transducer[5] is proportional to the aspect ratio (length/aperture) of the IDT. Thus, practical designs make a trade-off between aperture (finger length) and transducer length, i.e. between electrical and acoustic losses respectively. Further, the overlapping area between the busbars (See Fig. 1b) is also piezoelectrically active but in the

transverse direction (i.e along the aperture), where generated waves cannot be confined and result in additional acoustic losses[6]. In addition, the abrupt jump in the acoustic impedance between the periodic strips and busbar areas, respectively, promotes losses related to SAW scattering into bulk. Accordingly, the busbar sections of a resonator/filter themselves deteriorate the overall device Q. State-of-the-art SAW resonators operating at 2GHz have Q values not exceeding **500**. For comparison, the intrinsic Q values of the single crystalline materials typically used in the art are at least by an order of magnitude higher at similar frequencies.

The above observations underline the huge potential of the SAW technology yet to be realized provided one eliminates the major extrinsic losses. Further, SAW is a technology with great versatility providing solutions for a very wide range of applications and it would make a lot of economic sense to develop a technical solution for eliminating the associated extrinsic losses and make use of the full potential of this technology. Not the least, the BALUN (balance-to-unbalanced transformation) functionality also needed in mobile phone circuitry is difficult to realize with other filter design technologies. To exploit this potential of SAW, however, one needs to develop totally new design approaches ultimately resulting in a radical improvement of performance rather than perform incremental design optimizations. The proposers suggest that such a radical increase in performance can only be achieved by employing 2D and ultimately 3D design approaches. This assumption is supported by prior theoretical work[7-9] which demonstrates that periodic 2D surface structures allow the definition of omnidirectional (complete) acoustic bandgaps. The latter represent frequency regions over which propagation of elastic waves is forbidden, whatever their polarization and wave vector. In addition to their ability to behave like perfect mirrors, these structures can prove particularly useful for applications requiring a spatial confinement of acoustic waves and can therefore be used as acoustic filters or very efficient waveguides. The proposers have further developed these ideas and their contribution is summarized under the heading "*Preliminary results*" below to avoid repetition. The underlying idea proposed here is that the acoustic wave is excited at a frequency lying within the bandgap and hence cannot propagate in any direction, i.e. it is non-propagating. This eliminates automatically all propagation losses which are the major energy loss mechanism in an acoustic device. There exist strong indications that the elimination of the propagation losses would result in an increase of Q by up to an order of magnitude.

The Electroacoustic group at Uppsala University is one of the leading in the field authoring a range of new ideas and solutions ranging from materials synthesis through to device design, fabrication and electrical characterization and resulting in more than 100 publications in the field for the past decade. Inhere we summarize a few recent ones which have ultimately lead to the ideas in this proposal as follows.

a) *Thin film Lamb wave resonators in frequency control and sensing applications: a review*, [10] representing a topical review on thin film Lamb wave devices.

b) *High Performance Zero Group Velocity Resonator* (ZGVR) [11]. This development represents a new family of electroacoustic resonators employing a zero-group velocity mode, thus eliminating the need of reflectors and resulting in devices with smaller form factor and performance comparable and even better than state-of-the-art SAW technology.

c) *High Performance Inter-mode Coupled Thin Film Resonator* (IC-TFR) [12,13]. This work demonstrates a novel concept for the development of thin-film micro-acoustic resonators based on the coupling between different plate acoustic modes. More specifically, the lowest order symmetric S0 Lamb wave is excited and then coupled to the fundamental thickness shear bulk resonance by means of a metal strip grating with specific periodicity.

d) *Recent developments in thin film electro-acoustic technology for biosensor applications* [14], a review article putting into perspective our biosensor research during the past decade.

3. Project description

WP1. Development of Modeling Tools

WP1 provides the theoretical foundation of the whole project. Through a comprehensive theoretical description of the proposed surface phononic gratings it will develop efficient modeling tools (employing standard platforms such as COMSOL multyphysics) for the subsequent design and optimization work in WP2.

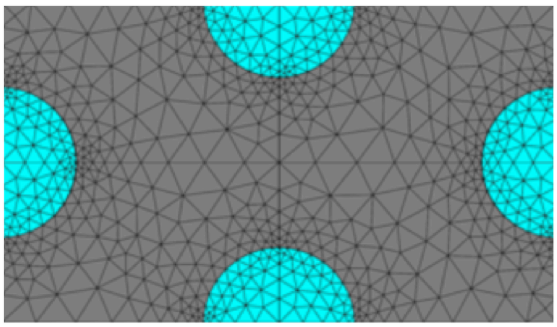

Figure 3. Top view of a single SPG cell

The employment of 2D surface phononic patterns/gratings (SPG) on single crystalline piezoelectric substrates, Fig. 3, (see also *Preliminary results* below for details) is meant to result in complete (omnidirectional) frequency bandgaps (i.e wave propagation is forbidden in any surface direction within a specific frequency range). The employment of such frequency bandgaps results in the elimination of SAW diffraction and hence in boosting the device Q factor. This WP aims at the theoretical analysis and subsequent identification of promising 2D phononic configurations. Important aspects to be considered include identification of the most suitable SPG symmetries and materials for specific SAW modes on various single crystalline piezoelectric substrates (AlN, $LiNbO_3$, $LiTaO_3$) as well as crystallographic cuts. Frequency response as well as Eigen-frequency analysis will be performed by means of finite element methods (FEM) considering infinite periodic structures with applied periodic boundary conditions. Initially, FEM models will be developed for SAW modes on c-oriented AlN substrates, in view of the in-plane surface symmetry which in turn will facilitate the interpretation of the results providing thus solid basis for the subsequent developments. Subsequently, the models will be further developed to cover the description of SPGs on anisotropic Lithium Niobate and Lithium Tantalate substrates. Specific emphasis will be put on commercially important substrates as Y-cut and 128°Y-cut $LiNbO_3$ (supporting high coupling SAW and Leaky-SAW modes), as well as on 36°Y-X $LiTaO_3$ supporting a high coupling leaky SAW mode. Further, SiO_2/36°Y-cut $LiTaO_3$ as well as SiO2/128°Y-cut $LiNbO_3$ temperature compensated substrates will be studied in view of complete phononic bandgap configurations. Here the emphasis will be on RF filter applications. The existence of complete bandgaps for the high coupling SAW and Leaky SAW modes on these substrates will be specifically addressed in view of boosting the QxK^2 product in the lower GHz range. A study on the most favorable topologies (geometrical shape) and size of the distributed masses will be performed for each crystal-wave combination and SPG symmetry. Further, novel transducers employing 2D phononic gratings will be theoretically studied in a complementary manner. Accordingly, the FEM models developed for the 2D phononic patterns will be further extended to cover the specific analysis of two-layer SPG transducers (see *Preliminary results*, the right hand side of fig. 4 and fig. 7). The latter models will be also used in the analysis of SPG based busbar configurations (periodic masses distributed directly on the busbar electrodes). The phononic patterns identified in this task will be employed in SPG based IDT configurations connected to the SPG based busbars (see Fig. 6 in *Preliminary results*) and studied. Electromechanical coupling coefficients and bandgap widths will be deduced from the FEM analysis. The results from this task are essential for optimal design of complete bandgap transducers and resonators. Thus, a 2D coupling-of-modes (COM) model for each specific case will be developed and subsequently employed for the numerical design of the actual resonators.

Specifically, the COM model will make use of the dispersion curves derived earlier by FEM models above. COM model is a parametric approach known for its robustness and accuracy while demanding very short computing times. It is noted that the applicants have sufficient expertise in the field of COM modeling and its adaptation to specific wave types such as surface transverse waves and Lamb waves [10].

WP2. Phononic bandgap devices for RF filter and sensor applications

Task 2.1. Design of SPG bandgap test devices

Initially, test resonant structures will be designed and subsequently fabricated and evaluated in Task 2.2 for the verification of the PGB modeling tools developed in WP1 and identification of the predicted bandgap characteristics. Both, the existence of complete bandgaps and the conditions for efficient wave excitation in the vicinity of the frequency bandgap will be experimentally studied and compared to the theoretical predictions. For this specific task we plan to design a variety of SPG transducer topologies in view of exciting SAWs in the main directions of strong interaction (see the Γ-K-M-Γ directions in fig. 5b) as determined in WP1. Suitable materials for both the piezoelectric substrate and the SPG grating along with their symmetries will be selected. Initially, highly symmetric piezoelectric crystals such as wurtzite c-oriented AlN will be used to demonstrate experimentally the potential of this specific grating technology as well as develop novel device topologies. Subsequently, phononic structures of practical relevance will be designed and subsequently fabricated and characterized on commercially available $LiNbO_3$ and $LiTaO_3$ substrates.

Task 2.2. Fabrication and evaluation of the SPG test devices

It is noted that the fabrication of SPG devices is fully compliant with the existing SAW technology and hence no specific technological development is needed here. The phononic grating will be made of high acoustic impedance metals such as W, Mo, Pt, Ir etc. deposited over the Al electrodes. The electrical admittance will be measured and compared to the initial theoretical results. The frequency stopband edges in each main direction will be identified from the admittance curve and subsequently compared to the theoretical predictions. Thus, the models developed in WP1 will be verified and if needed further optimized in an iterative manner to adequately describe the SPG nature as manifested experimentally. Further, Q-factor measurements will be performed on SPG test structures with varying apertures in order to demonstrate the expected decrease in diffraction losses as compared to those with narrow aperture SAW resonator topologies. Both, partial and complete bandgap test structures, will be manufactured by varying the thickness of the phononic gratings. The measurements planned will further help to deduce specific bandgap requirements for achieving sufficient suppression of SAW diffraction losses.

Task 2.3 Design and Fabrication of optimized PGB resonators for RF filter and biosensing applications

At this final stage, the knowledge gained from WP1 and the previous tasks of WP2 will be used for the design and subsequent fabrication of an optimized SAW resonators in the lower GHz range with Q factor exceeding **4000**. In addition to the measures proposed in WP2 bandgap alignment between the different building blocks will be performed by adjusting lithographically the shape and the size of the distributed masses in the respective building blocks. The measured resonator admittances will be further used in a ladder filter simulator to demonstrate the significant improvement of the filter capabilities in terms of insertion loss, out-of-band rejection and skirt. Filter performance will be compared with future specification requirements.

Another device design will employ the X-direction of Y-cut $LiNbO_3$ where a leaky SAW with extremely high electromechanical coupling exists. Our preliminary theoretical studies[1,2] show

that the SPG can modify the properties of the Leaky-SAW and covert them into a high electro-mechanical coupling shear-SAW which is suitable in-liquid operation. The high coupling will compensate the short-circuiting effect of the high dielectric permittivity of the water while the shear displacement is known to emanate relatively little mechanical energy into the water. This unique combination of shear displacement and strong electro-mechanical coupling is going to boost the sensing performance of these types of (gravimetric) biosensors. The device will be designed to operate in the range of 200MHz where sensitivity measurements are more robust. In-liquid operation will be comprehensively characterized. Specifically, ultimate mass, density and viscosity resolution will be experimentally determined.

Timetable

	1st year	2nd year	3rd year	4rd year	Deliverable	
					Nature	Month
WP1	FEM Models, SPG identified	Model Verification, SPG optimization, COM model			FEM models and theoretical results	12
WP2						36, 48
Task 2.1		Test structures (TS) designed			Masks set	24, 36
Task 2.2		TS Fabricated, measurements, iterations	SPG resonator design for both telecom and biosensor cases	Optimized SPG Resonators and filter design	SPG Test & Evaluation	24, 36
Task 2.3			Resonators fabrication, evaluation	Optimized SPG device fabrication, evaluation	Resonator, filter design Resonator evaluation SPG - biosensor	36 42 48

4. Preliminary results

Among the variety of phononic crystals (PCs) the research interest of the proposers has focused on those employing surface acoustic waves due to their low fabrication complexity as well as the ability to operate in the RF frequency range[1-3]. 2D PCs can also be practically realized on the surface of the substrate in very much the same way as 1D periodic metal gratings widely employed in the SAW technology[2, 3]. As illustrated in Fig. 4, a 2D grating can be formed by defining a discrete 2D mass-loading pattern superimposed with the IDT aluminum fingers (with alternating electric potentials denoted by red and blue at the left side in Fig. 4). Further, the thickness of the loading material (usually a high density metal - Mo, Pt, W, etc.) is sufficiently small, thus making the latter approach fully compatible with the standard SAW planar technology.

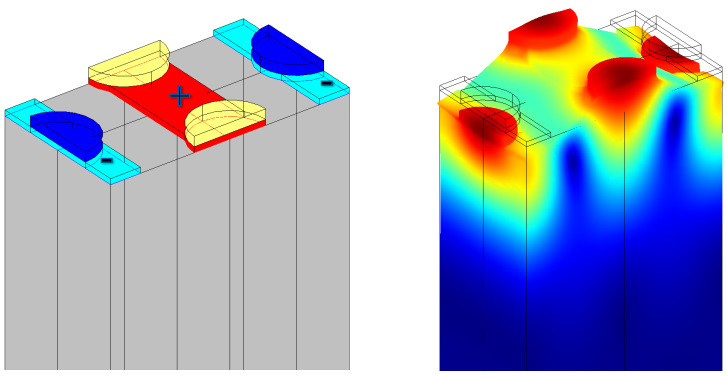

Figure 4. A novel 2D SAW transduction cell formed by heavy masses onto a regular SAW grating structure used in IDTs

Our theoretical studies[3] on low profile 2D phononic metal gratings (Fig. 5a) have predicted the existence of an omni-directional (complete) SAW band gap above a specific critical thickness of the phononic grating (Fig. 5b). The natural frequencies of SAW excitation has been found to coincide with one of the frequency edges of the band gap (Fig. 5c).

Note the specific selection of symmetry and material combinations to allow complete bandgap performance with low profile topologies. More specifically, the hexagonal SPG symmetry of c-oriented AlN exhibits a relatively small separation between the Bragg frequencies in the M and K directions of the Brillouin zone (frequency ratio of just about 1.1547), which in turn promotes the overlap between the bandgaps formed around the above Bragg frequencies. Such an overlap is desired since it determines the existence of a complete bangap in the structure. Thus, a complete bandgap characteristics can be achieved by a relatively thin SPG masses fabricated by means of the planar technology, while in the same time keeping the overall SAW loading relatively low to suppress bulk scattering and other energy transformation effects.

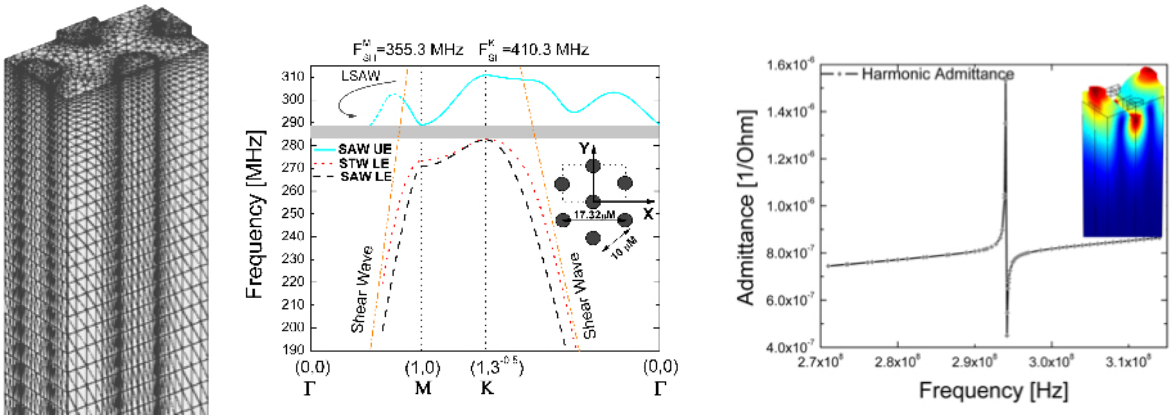

Figure 5. Surface phononic grating (a) Topology – single cell (b) Bandgap Structure (c) Harmonic Admittance [2]

The above findings provide a solid theoretical basis for studying SPG and subsequently designing high performance micro- and nano-acoustic SAW devices exhibiting diminished diffraction losses owing to the unique properties of the omnidirectional bandgap structure. Further the SPG approach adds versatility regarding the SAW excitation. Three distinct SPG transducer topologies, without an analog in the 1D design, have been proposed just recently by us [3]. More specifically (see as fabricated in Fig. 6) these are the M-mode SPG transducer, the M-Transversal mode transducer and the K-mode transducer, exciting SAWs at the edges of the band gap at the M and K points of the Brillouin zone, respectively.

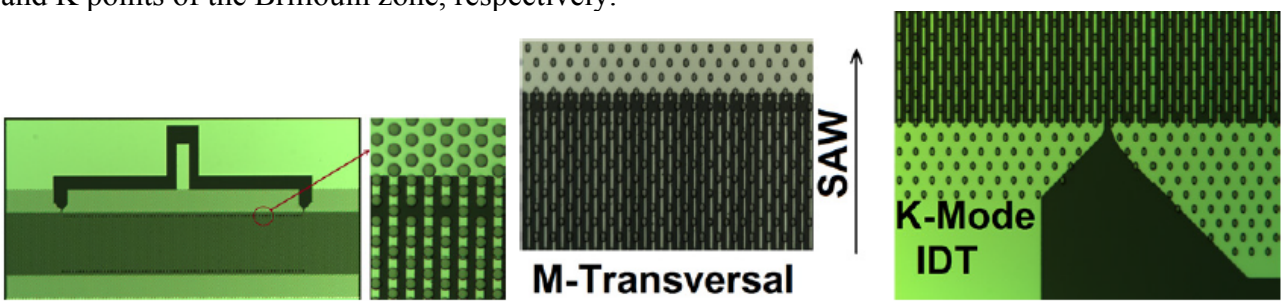

Figure 6. Three distinct types SPG based resonant test structures as demonstrated recently - the M-mode [15], the Transversal-M mode [2, 15] and the K-mode transducers[15], respectively.

It is also noted that the M-transversal mode transducer is able to excite SAW in direction orthogonal to the applied electric field (i.e along the device aperture). Our preliminary theoretical

results show that wave excitation orthogonal the applied electric field is possible (Figure 7) and can open the way for designing SAW devices with unique properties. An experimental proof of this idea has been reported by the applicants just recently [2].

The above transducer and reflector topologies will serve as a base for the development of low loss RF devices employing complete band gap SPG reflectors, transducers and busbars, respectively. Bandgap matching, between the different building blocks will be developed to eliminate SAW scattering into the bulk induced by the acoustic impedance mismatch between them. The idea of bandgap alignment based designs is novel for micro-acoustic devices and is reminiscent of the design approaches used in semiconductor devices. Here we aim at the development of a SAW technological platform yielding Q factors in excess of 4000 at 2GHz, which represents at least an 8-fold improvement over the state-of-the-art. It is noted that the intrinsic material Q at this frequency is in the range of 10^4 to 10^5, representing the inherent physical limits.

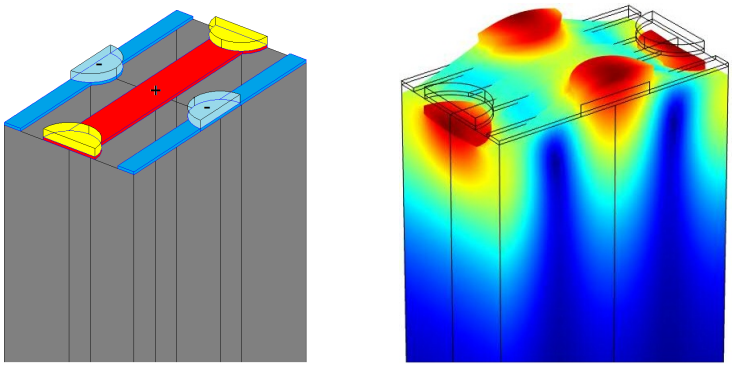

Figure 7. Transversal-mode SAW 2D transduction cell: the electric field is othrogonal to the direction SAW mode propagation due to the specific energy localization under the 2D masses

5. Significance

The importance of this topic was promptly recognized by the community and resulted in an invited talk at the 2014 European Frequency and Time Forum where initial experimental results on the topic were presented by one of the applicants[15]. Noteworthy, the number of publicatons on the topic has increased rapidly in the last few years. The proposed research will provide a substantial impetus to the field in that it develops a fundamentally new theoretical framework for the design of electroacoustic RF passive components with applications in wireless communications and sensors. The group is at the forefront in the field of the phononic crystal approaches to filter and sensor applications and this proposal is of strategic importance for the proposers by aiming at strengthening these leading positions as well as further advancing this field of research. Current focus is on 2D design topologies but the results would lay the ground for future 3D topologies. In this context, our work on SAW/BAW inter-mode coupling[13] is just an indication of a range of other 3D possibilities.

From the application point of view this proposal has the potential to generate a breakthrough in the research for high performance components for signal processing applications. By way of example we consider frontend filters in wireless communications. The industry has been driven initially by mobile phones and later by smart internet centric devices. This trend towards data centric services will further drive the bandwidth requirements of cellular systems. Unfortunately, the fragmentation of the different cellular bands continued at an increasing pace during the last decade. Worse yet, this development is accelerated by the introduction of new bands. Especially in 4G we see that the

new bands have generally a comparatively small bandwidth and have sometimes very small duplex spacing. As a result, recent communication band allocations define a more efficient use of spectrum, and thus require filters with extreme performance. To meet the requirements of these bands, a radical improvement in acoustic filter technology is currently needed. Further, the smartphone technology critically depends on high performance and low-loss filters/duplexers to increase the time the battery lifetime in typical usage situations.

The proposed developments have the potential to significantly increase the performance of modern communication systems as well as decrease both the power consumption and fabrication cost. The development of more efficient filtering approaches is further expected to lead to additional circuit simplifications on a system level. Rx filters, for instance, for 4G LTE have a typical insertion loss in the range -3.5dB and -2dB. Noteworthy, a loss of -3.5dB means that 55% of the signal power from the antenna is lost at the very first radio component effectively meaning that the signal-to-noise ratio has deteriorated accordingly. This loss can only be compensated by increasing the radiated power at the base station by 110%. The power efficiency of a base station is about 4 to 6% which only underlines the importance of keeping the signal loss low in view of power efficiency of wireless communications. Future wideband generations would require an insertion loss of -1dB and better which corresponds to a signal loss of about 20%. The current proposal aims at developing technologies that would allow to bring the insertion losses down to -0.5dB and better, resulting in much higher signal-to-noise ratio and hence equally higher data-rates (at constant signal power) than state of the art today through the Shannon–Hartley theorem. Specifically, higher Q would result in a lower insertion loss and a larger bandwidth of the filter, hence, in larger data rates. The bandwidth would also gain directly through the increased coupling.
Finally, although RF communications are in the focus of the work the results obtained would be equally useful for a wide range of other applications including ultralow noise oscillators, sensors, wireless sensor networks, passive RFIDs, time control applications, ultrahigh precision radars, etc. In this context, the biosensor to be developed here is not a mere illustration but rather a demonstration of the new capabilities of micro-acoustic RF technologies. The leap advantages of RF micro-acoustic sensors as compared to Quartz Crystal Microbalance are the much smaller form factor (size) and the associated with it extreme sensitivity ($\sim f^2$). Combining these characteristics with MEMS microfluidic and/or micro-pipetting provides a powerful method for combinatorial biosensing and bioanalysis. Specifically in the project, the possibility of *efficiently* exciting a *shear* wave combined with the elimination of associated propagation losses would represent a real breakthrough in the biosensor field. In other words, the high coupling (K^2) will result in a high *dynamic range* in terms of viscosity, the low losses would result in *extreme resolution* while the small size would allow *multiplexing* as well as efficient use of chemicals and analytes.

6. Equipment

The Clean Room facilities at UU (part of MyFAB) are at our disposal and more than adequate for the execution of the experimental work envisaged. In addition, we have our own specialized laboratory for RF characterization. Uppsala University has a sufficient number of COMSOL licenses which the applicants routinely use in their work. The applicants have also significant theoretical and experimental expertise in the field to efficiently and successfully perform the research proposed.

7. National and international collaboration

While the proposed project deals in detail with the fundamental theory and performance of the SPGs, the applicants have established strong collaborations with European companies and research entities such as EPCOS AG, GVR Trade SA, FEMTO ST, Berkeley Sensors and Actuators Center and the Politechnical University of Madrid. Further, the results from the forskarassistent grant VR 2009-5056 to the co-applicant served as the basis of the future developments envisaged in the

"ALambRHa",12-1303 EURIPIDES labeled project on Lamb wave sensors for harsh environments, in collaboration with AAC Microetec AB, CEA Leti and SENSeOR SAS, France. The applicants have also established direct collaborations also with Sand9, Inc. USA, Triquint Semicondutors Inc. USA, etc. The main applicant has a long record of supervising and coordinating both EU and national projects and programs such as MEDCOM 1999-11411 EU project "Microwave electroacoustic devices for mobile and land based communications" coordinated by I.Katardjiev, Vinnova project (2003-2005) "Real time sensing artificial dog's nose using thin film resonant biosensors ", in direct collaboration with Biosensor AB, director I.Katardjiev; SSF framework in microelectronics (2003-2007) "Integration studies between the EA and IC technology", director I.Katardjiev; EU proj. (2005-2008) "Integrated biosensor system for label-free in-vitro DNA and protein diagnostics" coordinated by Siemens; Vinnex Center of Excellence WISENET (2007-2016); The Swedish Space Agency, "Wireless sensors in high temperature and ionizing radiation applications", 2013 - 2014, feasibility project in cooperation with AAC Microetec, Sweden; VR Industridoktorand with RADI Medical AB, VR framework programme "Moderna elektroakustiska thinnfilms komponenter för informations och kommunikationssystem" coordinated by S.Gevorgian, Chalmers, etc.

References

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[9] S. Benchabane, A. Khelif, J.-Y. Rauch, L. Robert, and V. Laude, "Evidence for complete surface wave band gap in a piezoelectric phononic crystal, " *Phys. Rev. E*, vol. 73, art. no. 065601, 2006.

[10] V. Yantchev and I. Katardjiev, "Thin film Lamb wave resonators in frequency control and sensing applications: a review", TOPICAL REVIEW in *J. Micromech. Microeng.,* Vol. 23 (4) 2013.

[11] V. Yantchev, L. Arapan, I. Katardjiev and V. Plessky, "Thin-film zero-group-velocity Lamb wave resonator ", *Appl. Phys. Lett.* 99, 033505 (2011)

[12] V. Yantchev, V. Plessky and I. Katardjiev, "Fundamentals of the grating-assisted surface acoustic wave–plate bulk acoustic wave interaction", *J. Appl. Phys*. Vol. 104, art. no. 034111, 2008

[13] L. Arapan, I. Katardjiev and V. Yantchev, "An intermode-coupled thin-film micro-acoustic resonator", *J. Micromech. Microeng.*, Vol. 22, No. 8, art.no 085004, 2012

[14] I. Katardjiev and V. Yantchev, "Recent developments in thin film electro-acoustic technology for Biosensor
applications", *Vacuum 86*, pp.520-531, 2012

[15] V. Yantchev, "Surface Phononic Gratings as building blocks of RF Transducers and Reflectors with complete bandgap characteristics", Invited Talk at the *2014 European Freq. and Time Forum*, Switzerland, pp 1-10, 2014

Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

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Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project

	Role in the project	Name	Percent of full time
1	Applicant	Ilia Katardjiev	30
2	Participating researcher	Ventsislav Yanchev	50
3	Participating researcher	Ventsislav Yantchev	

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	2019	Total
1	Applicant	Ilia Katardjiev	30	295,200	302,400	310,800	320,124	1,228,524
2	Participating researcher	Ventsislav Yanchev	50	396,000	408,000	420,000	432,600	1,656,600
	Total			691,200	710,400	730,800	752,724	2,885,124

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

	Type of premises	2016	2017	2018	2019	Total
1	Laborativ lokal	10,000	10,000	10,000	10,000	40,000
2	Kontor	15,000	15,000	15,000	15,000	60,000
	Total	25,000	25,000	25,000	25,000	100,000

Running Costs

	Running Cost	Description	2016	2017	2018	2019	Total
1	Renrums avgift	Tillträde till renrum	60,000	60,000	60,000	60,000	240,000
2	Material	Piezoelektriska substrat		15,000	30,000	10,000	55,000
3	Resor	Konferens	20,000	20,000	20,000	20,000	80,000
4	Publikationer	Open access tidskrifter	5,000	5,000	5,000	5,000	20,000
	Total		85,000	100,000	115,000	95,000	395,000

Depreciation costs

	Depreciation cost	Description	2016	2017	2018	2019

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	2018	2019	Total, applied	Other costs	Total cost
Salaries including social fees	691,200	710,400	730,800	752,724	2,885,124		2,885,124
Running costs	85,000	100,000	115,000	95,000	395,000		395,000
Depreciation costs					0		0
Premises	25,000	25,000	25,000	25,000	100,000		100,000
Subtotal	801,200	835,400	870,800	872,724	3,380,124	0	3,380,124
Indirect costs	232,860	243,120	253,740	254,317	984,037		984,037
Total project cost	1,034,060	1,078,520	1,124,540	1,127,041	4,364,161	0	4,364,161

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

The main applicant is going to work on the project to a level of 30% while the coapplicant is envisaged to work halftime on the project, hence the personnel costs. A 3% annual salary raise in included in the budget. The rest of the costs are obvious running costs such as access to the Ångström Clean Room facility where all experimental work will be performed apart from the electrical measurements. The latter will be performed at a measurement lab set up by the proposers. To this end only rent on premises is planned. Further running costs include materials, conference attendance, office rent and publication costs. The only materials costs (not provided by the Clean Room) are the piezoelectric substrates and some rare metals as described in the Workplan.
The indirect costs are at a level of 30%. Overhead is not calculated on rent of premises and offices.

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	2018	2019

CV

Table of contents

Curriculum vitae of Ilia Katardjiev

Name, Date of birth: Ilia Katardjiev, 1955-04-23
Affiliation: Solid-State Electronics, Engineering Sciences, Uppsala University

1. Master's degree (1983, Theoretical Physics, Sofia University, Bulgaria)
2. PhD degree (1989, Electrical Engineering, Title: *Theoretical and experimental studies of surface evolution during ion bombardment, Supervisor: Prof. G.Carter, Salford University, UK*)
3. Post Doc (1991-1993, Uppsala University)
4. Docent (Uppsala University, 1997)
5. Current position: Professor in electronics, Uppsala University, (2005)
6. Director of undergraduate studies, Dept. Engineering Sciences, since 2012

6. Previous positions

2005-2009, Acting Head of the Department of Solid State Electronics
2005, Professor in Solid State Electronics, Uppsala University
2004, University lecturer, Uppsala University
1997, Associate Professor, Uppsala University
1994, Research scientist, Uppsala University
1989-1990, Research scientist, Bulgarian Academy of Sciences

7. Supervision of doctoral students (PS: principal supervisor; CS: co-supervisor)

Anna Barklund, 1992 (CS)
Christer Hedlund, 1997 (CS)
Lars B Jonsson, 1999, (CS)
Pelle Rangsten, 1999, (CS),
Fredrik Engelmark, 2002, (PS)
Gonzalo Fuentes, 2003, (PS)
Jörgen Westlinder, 2004, (CS)
Örjan Vallin, 2005, (CS)
Mats Jönsson, 2006, (CS)
Daniel Rosén, 2006, (PS)
Johan Bjurström, 2007, (PS)
Gunilla Wingqvist, 2009, (PS)
Johannes Enlund, 2009, (PS)
David Martin, 2009, (PS)
Henrik Andersson, 2009, (PS)
Emil Anderås, 2012, (PS)
Lina Liljeholm, 2012, (PS)
Lilia Arapan, 2012, (CS)
Milena Moreira, 2014, (PS)

Supervision of post-doctoral fellows

C. Cho, 2003
Nicu Scarisoreanu, 2004
Ventsislav Yantchev, 2005
Tomas Kubart, 2007

8. National and international assignments of importance

Guest Editor of *Vacuum*

Member of the Technical Programme Committee member of IEEE-Ultrasonic Symposium

Member of the international Committee of VEIT

Member of the Advisory Board of the International Conference on Plasma Surface Engineering

Member of Rådsforskarnämnden, VR

9. Major research involvements

1980-1983	Development of Schottky diodes based on metal silicides
1986-1989	Development of the General Theory of Surface Evolution
1987-1994	Development of Numerical Methods and computer programs for both 2D and 3D modelling of surface evolution (used in VLSI process simulation)
1991-1998	Development of the dynamic TRIM code T-DYN and dynamic simulations of ion-solid interactions (ion assisted deposition, preferential sputtering, discovery of the sputter yield amplification effect, etc)
Since 1998	Development of the Thin Film Electro-Acoustic (TEA) Technology
2000-2003	Coordinator of a EU project MEDCOM (1999-11411) in which together with Philips, Ericsson, Thomson, Unaxis and EPFL the TEA filter technology was first developed in Europe - primarily for mobile communications in microwave frequencies.
2002-2004	Developed an original process an original process for the synthesis of textured wurtzite thin films with a tilted c-axis. Such a texture is needed for the fabrication of shear wave electro-acoustic transducers employed in biosensors.
2003-2007	Director of an SSF framework programme in microelectronics "Integration studies between the TEA and IC technologies"
2005-2008	Participated in a EU project BIOGNOSIS in which a fully integrated biosensor array for protein and DNA analysis was developed
Since 2000	Theoretical and experimental development of a range of thin film electro-acoustic components for telecom and sensor applications
2007-2014	Co-applicant in the Vinnex WISENET Center of Excellence and a Deputy Director of the Center
2010-2013	Co-applicant in a VR framework programme "Novel thin film electro-acoustic components for information and communications systems".

10. Entrepreneurial achievements

Co-founder of a software company Bitlane AB

Co-founder of a research company "Forskarbolaget AB"

CURRICULUM VITAE, Ventsislav Yantchev

Name: Ventsislav Yantchev, **born May 22th, 1976**
Associate Professor (Docent) in Electronics

1. **Higher education degree:** *2000*, M.Sc. in Microelectronics and Information technologies by University of Sofia, Sofia, Bulgaria
2. **Doctoral degree:** *Dec. 2003*. Ph.D in Microwave Physics wit specialization on microwave acoustics. Tesis title: "Analysis of Surface Transverse Waves on Quartz in Resonant Structures for Oscillator and Sensing Applications", supervisor: Prof. Vesselin Strashilov, Dept. Solid State Physics and Microelectronics, Faculty of Physics, University of Sofia, Sofia, Bulgaria, E-mail: ves@phys.uni-sofia.bg.
3. **Postdoctoral positions:** *Sept. 2004–June 2006*, Dept. Solid State Electron., Uppsala Univ., Uppsala, Sweden.
4. **Docent at Uppsala University,** *November 2011*
5. Research Assistant (**VR Forskarassitent**), 2010-2014 at Dept. Solid State Electronics, The Angstrom Lab., Uppsala University, Uppsala, Sweden

   The position requirements could be divided into two aspects. The first aspect concerns exploration of advanced ideas in the micro-acoustic technology and applications. This includes both theoretical and experimental research. The main focus is on the development of innovative and high performance electroacoustic devices for Frequency Control, Signal Processing and Sensing applications utilizing electro-acoustic components operating in the microwave frequency range. For this purpose the standard CMOS technology and the recently developed thin film technology in combination with various electro-acoustic phenomena (well known as well as recently discovered) are employed for the development of a new family of low cost high performance devices. The second aspect involves work in a research group, that is, participating in various research projects and assisting graduate and undergraduate students in their pursue of Ph.D and M.Sc respectively at the Dept. Solid State Electronics, Uppsala University.

6. **Previous positions and periods of appointment:**

   2002 – 2003 Marie Curie Fellowship at Dept. Solid State Electronics, The Angstrom Lab., Uppsala University, Uppsala, Sweden

   2004-2006 Postdoc at at Dept. Solid State Electronics, The Angstrom Lab., Uppsala University, Uppsala, Sweden

   2006-2010 Researcher at Dept. Solid State Electronics, The Angstrom Lab., Uppsala University, Uppsala, Sweden

   2010-2011 Research Assistant (VR Forskarassitent) at Dept. Solid State Electronics, The Angstrom Lab., Uppsala University, Uppsala, Sweden

7. **Interruptions in research.** *January 2004 – July 2004*, Military Service.
8. **Main Supervision:** Dr. Lilia Arapan, Ph.D in *Sept. 2012*, Dr. Emil Anderas, Ph.D in *May 2012*. **Assisting (with large contribution) supervisor** of Dr. Gunilla Wingqvist (Ph.D, *2009*)
9. **Other information that is relevant to your application.**

   The applicant is member of scientific committee in two groups of the European Frequency and Time Forum – the *Materials, Resonators, & Resonator Circuits* and the *Sensors & Transducers*, respectively.

   The applicant serves regularly as a referee of the *J. Micromech. Microeng.*, *J. Microelectromech. Syst*., and *IEEE Sens. J.*

Awards and Honors:
1. Research Assistant position by the **Swedish Research Council (VR)**, *2010-14*
2. Younger researcher grant from the **Göran Gustaffsons Stiftelse (GG),** *2009*
3."Vision" prize from the **Angstrom Material Academy**, *2009, 2011*
4. Two invited talks in 2012 and one topical review article (April 2013) all in direct relation to the VR Research Assistant (Forskarassitent) Grant. One invited talk in relation to the current proposal (EFTF 2014).
5. Three student competition awards, from the European Frequency and Time Forum, under the direct supervision of the applicant.

Teaching: Novel courses introduced by the applicant:
1. Electro-acoustic and Acousto-optic Components - Regular C - Course at UU, 4.5ph , *2006 - 2010*
2. Pizo-MEMS for Telecom and Sensor Applications, *2010* Advanced Training Class at the Technical University of Sofia, Bulgaria, Dept. Communications & Electronics, funded by the "German Marshal Fund"
3. Advances in the Thin Film Microacoustic Resonators Technology, *2011* Advanced Training Class at GVR Trade SA, Switzerland
4. Piezoelectric micromechanical systems in telecom and sensor applications, invited regular course at the Technical university of Sofia, *Since 2013*

Consulting:
Consulting: Project "Analysis and Synthesis of Thin Solid and Organic Films for Sensing Applications", No. VU-F-203/2006, National Scientific Fund of Bulgaria
Scientific advisor of M.Sc. Teona Mirea, currently a Ph.D student at the Polytechnical University of Madtrid, Spain.

Publication list

Table of contents

I. Publications of Ilia Katardjiev

A) Peer-reviewed original articles

1. Deposition of highly textured AlN thin films by reactive high power impulse magnetron sputtering
By: Moreira, M.A.; Torndahl, T.; Katardjiev, I.; et al.
Journal of Vacuum Science & Technology A (Vacuum, Surfaces, and Films) Volume: 33 Issue: 2 Pages: 021518 (5 pp.) Published: March 2015

Times Cited: 0

2. Thin film Lamb wave resonators in frequency control and sensing applications: a review
By: Yantchev, Ventsislav; Katardjiev, Ilia
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 23 Issue: 4 Article Number: 043001 Published: APR 2013

Times Cited: 6

3. Efficient RF voltage transformer with bandpass filter characteristics
By: Moreira, M.; Bjurstrom, J.; Katardjiev, I.; et al.
ELECTRONICS LETTERS Volume: 49 Issue: 3 Pages: 198-199 Published: JAN 31 2013
Full Text from Publisher

Times Cited: 0

4. An intermode-coupled thin-film micro-acoustic resonator
By: Arapan, Lilia; Katardjiev, Ilia; Yantchev, Ventsislav
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 22 Issue: 8 Article Number: 085004 Published: AUG 2012

Times Cited: 2

5. Tilted c-Axis Thin-Film Bulk Wave Resonant Pressure Sensors With Improved Sensitivity
By: Anderas, Emil; Katardjiev, Ilia; Yantchev, Ventsislav M.
IEEE SENSORS JOURNAL Volume: 12 Issue: 8 Pages: 2653-2654 Published: AUG 2012
Full Text from Publisher

Times Cited: 1

6. Surface acoustic wave induced particle manipulation in a PDMS channel-principle concepts for continuous flow applications

By: Johansson, Linda; Enlund, Johannes; Johansson, Stefan; et al.
BIOMEDICAL MICRODEVICES Volume: 14 Issue: 2 Pages: 279-289 Published: APR 2012
Full Text from Publisher

Times Cited: 16

7. Surface acoustic wave-induced precise particle manipulation in a trapezoidal glass microfluidic channel
By: Johansson, L.; Enlund, J.; Johansson, S.; et al.
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 22 Issue: 2 Article Number: 025018 Published: FEB 2012

Times Cited: 8

8. Recent developments in thin film electro-acoustic technology for biosensor applications
By: Katardjiev, I.; Yantchev, V.
VACUUM Volume: 86 Issue: 5 Special Issue: SI Pages: 520-531 Published: JAN 5 2012
Full Text from Publisher

Times Cited: 18

9. Synthesis and characterization of (0001)-textured wurtzite Al1-xBxN thin films
By: Liljeholm, L.; Junaid, M.; Kubart, T.; et al.
SURFACE & COATINGS TECHNOLOGY Volume: 206 Issue: 6 Pages: 1033-1036 Published: DEC 15 2011
Full Text from Publisher

Times Cited: 1

10. Sensitivity Features of Thin Film Plate Acoustic Wave Resonators
By: Arapan, Lilia; Anderas, Emil; Katardjiev, Ilia; et al.
IEEE SENSORS JOURNAL Volume: 11 Issue: 12 Pages: 3330-3331 Published: DEC 2011
Full Text from Publisher

Times Cited: 7

11. Lamb wave resonant pressure micro-sensor utilizing a thin-film aluminium nitride membrane
By: Anderas, E.; Katardjiev, I.; Yantchev, V.
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 21 Issue: 8 Article Number: 085010 Published: AUG 2011

Times Cited: 4

12. Thin-film zero-group-velocity Lamb wave resonator
By: Yantchev, Ventsislav; Arapan, Lilia; Katardjiev, Ilia; et al.

APPLIED PHYSICS LETTERS Volume: 99 Issue: 3 Article Number: 033505 Published: JUL 18 2011

Times Cited: 6

13. Highly Mass-Sensitive Thin Film Plate Acoustic Resonators (FPAR)
By: Arapan, Lilia; Alexieva, Gergana; Avramov, Ivan D.; et al.
SENSORS Volume: 11 Issue: 7 Pages: 6942-6953 Published: JUL 2011
Full Text from Publisher

Times Cited: 6

14. Systematic investigation of biomolecular interactions using combined frequency and motional resistance measurements
By: Anderson, Henrik; Wingqvist, Gunilla; Weissbach, Thomas; et al.
SENSORS AND ACTUATORS B-CHEMICAL Volume: 153 Issue: 1 Pages: 135-144 Published: MAR 31 2011
Full Text from Publisher

Times Cited: 3

15. FBAR Sensor Array for in Liquid Operation
By: Enlund, Johannes; Martin, David M.; Yantchev, Ventsislav; et al.
IEEE SENSORS JOURNAL Volume: 10 Issue: 12 Pages: 1903-1904 Published: DEC 2010
Full Text from Publisher

Times Cited: 1

16. Fabrication and characterization of a shear mode AlN solidly mounted resonator-silicone microfluidic system for in-liquid sensor applications
By: Sharma, Gunjana; Liljeholm, Lina; Enlund, Johannes; et al.
SENSORS AND ACTUATORS A-PHYSICAL Volume: 159 Issue: 1 Pages: 111-116 Published: APR 2010
Full Text from Publisher

Times Cited: 6

17. A micromachined Stoneley acoustic wave system for continuous flow particle manipulation in microfluidic channels
By: Yantchev, Ventsislav; Enlund, Johannes; Katardjiev, Ilia; et al.
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 20 Issue: 3 Article Number: 035031 Published: MAR 2010

Times Cited: 9

18. Micromachined Thin Film Plate Acoustic Wave Resonators (FPAR): Part II
By: Yantchev, Ventsislav; Arapan, Lilia; Katardjiev, Ilia
IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 56 Issue: 12 Pages: 2701-2710 Published:

DEC 2009
Full Text from Publisher

Times Cited: 17

19. Thick NiSi Electrodes for AlN Electroacoustic Applications
By: Martin, D. M.; Smith, U.; Yantchev, V.; et al.
ELECTROCHEMICAL AND SOLID STATE LETTERS Volume: 12 Issue: 5 Pages: H182-H184 Published: 2009

Times Cited: 0

20. Significant configurational dependence of the electromechanical coupling constant of B0.125Al0.875N
By: Tasnadi, Ferenc; Abrikosov, Igor A.; Katardjiev, Ilia
APPLIED PHYSICS LETTERS Volume: 94 Issue: 15 Article Number: 151911 Published: APR 13 2009

Times Cited: 7

21. A micromachined thermally compensated thin film Lamb wave resonator for frequency control and sensing applications
By: Wingqvist, G.; Arapan, L.; Yantchev, V.; et al.
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 19 Issue: 3 Article Number: 035018 Published: MAR 2009

Times Cited: 26

22. Improved Properties of AlON/4H-SiC Interface for Passivation Studies
By: Wolborski, M.; Martin, D. M.; Bakowski, M.; et al.
Edited by: Suzuki, A; Okumura, H; Kimoto, T; et al.
Conference: International Conference on Silicon Carbide and Related Materials Location: Otsu, JAPAN Date: OCT 14-19, 2007
Sponsor(s): Japan Soc Appl phys; Assoc Promot Elect, Elect & Informat Engn; Ceram Soc Japan; IEEE EDS, Kansai Chapter; IEEJ; Inst Elect, Informat & Commun Engineers; Japanese Assoc Crystal Growth; Surface Sci Soc Japan; Vacuum Soc Japan
SILICON CARBIDE AND RELATED MATERIALS 2007, PTS 1 AND 2 Book Series: Materials Science Forum Volume: 600-603 Pages: 763-766 Published: 2009

Times Cited: 1

23. Oscillators Based on Monolithically Integrated AlN TFBARs
By: Norling, Martin; Enlund, Johannes; Katardjiev, Ilia; et al.
IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES Volume: 56 Issue: 12 Pages: 3209-3216 Published: DEC 2008
Full Text from Publisher

Times Cited: 4

24. Mass sensitivity of multilayer thin film resonant BAW sensors
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Book Group Author(s): IEEE
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Times Cited: 6

2. Recent developments in thin film electro-acoustic technology for biosensor applications
By: Katardjiev, I.; Yantchev, V.
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E) Patents

1. I.Katardjiev, J.Bjurström, G.Wingqvist, Production of polycrystalline films for shear mode piezoelectric thin film resonators , Swedish patent application #0500647-3, 2005

2. I.Katardjiev, J.Bjurström, G.Wingqvist, Production of polycrystalline films for shear mode piezoelectric thin film resonators , PCT/SE2006/050041, 2006 (granted)

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4. V.Yantchev, L.Johansson, J.Enlund, I.Katardjiev, (WO/2010/123453), International Application No.: PCT/SE2010/050455, " DEVICE AND METHOD FOR MANIPULATING PARTICLES UTILIZING SURFACE ACOUSTIC WAVES, 2010, (granted)

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F) Open access computer programs

1. 2Dinese – a full scale 2D topography simulator
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II. Publications of Ventsislav Yantchev

A) Peer-reviewed original articles

1. Influence of liquid properties on the performance of S-0-mode Lamb wave sensors: A theoretical analysis
By: Mirea, Teona; Yantchev, Ventsislav
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2. A transversely coupled phononic surface acoustic wave transducer
By: Yantchev, V.
APPLIED PHYSICS LETTERS Volume: 104 Issue: 10 Article Number: 103503 Published: MAR 10 2014

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By: Lin, Chih-Ming; Yantchev, Ventsislav; Zou, Jie; et al.
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By: Arapan, Lilia; Alexieva, Gergana; Avramov, Ivan D.; et al.
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By: Yantchev, Ventsislav; Enlund, Johannes; Katardjiev, Ilia; et al.
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Conference: 17th International Vacuum Congress/13th International Conference on Surface Science/Internatinal Conference on Nanoscience and Technology Location:

Stockholm, SWEDEN Date: JUL 02-06, 2007
Sponsor(s): Swedish Vacuum Soc
PROCEEDINGS OF THE 17TH INTERNATIONAL VACUUM CONGRESS/13TH INTERNATIONAL CONFERENCE ON SURFACE SCIENCE/INTERNATIONAL CONFERENCE ON NANOSCIENCE AND TECHNOLOGY Book Series: Journal of Physics Conference Series Volume: 100 Article Number: 042014 Published: 2008
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By: Bjurstrom, J; Yantchev, V; Katardjiev, I
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By: Yantchev, VM; Katardjiev, IV
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By: Strashilov, VL; Yantchev, VM
IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 52 Issue: 5 Pages: 812-821 Published: MAY 2005
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By: Bjurstrom, J; Katardjiev, I; Yantchev, V
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Times Cited: 16

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Times Cited: 6

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By: Strashilov, VL; Djordjev, KD; Yantchev, VM
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Times Cited: 8

B) Peer-reviewed conference contributions

1. Phononic SAW Transducers with Complete Frequency Bandgap Characteristics
By: Yantchev, Ventsislav; Plessky, Victor
Book Group Author(s): IEEE
Conference: 1st IEEE International Frequency Control Symposium (FCS) Location: Taipei, TAIWAN Date: MAY 19-22, 2014
Sponsor(s): IEEE; UFFC; Asia Pacific Metrol Programme; Minist Sci & Technol; NAR Labs; Instrument Technol Res Ctr; Sensors & Actuators Tech; Tsing Hua Univ
2014 IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM (FCS) Book Series: IEEE International Frequency Control Symposium Pages: 508-509 Published: 2014

Times Cited: 0

2. Suppression of transverse-mode spurious responses in thin film Lamb wave resonators by bandgap engineering
By: Yantchev, V.; Mirea, T.
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2014 IEEE International Ultrasonics Symposium (IUS) Pages: 2552-5 Published: 2014

Times Cited: 0

3. AlN solidly mounted resonators for high temperature applications
By: Mirea, T.; DeMiguel-Ramos, M.; Clement, M.; et al.
Conference: 2014 IEEE International Ultrasonics Symposium (IUS) Location: Chicago, IL, USA Date: 3-6 Sept. 2014
2014 IEEE International Ultrasonics Symposium (IUS) Pages: 1524-7 Published: 2014

Times Cited: 0

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By: Mirea, T.; Iborra, E.; Yantchev, V.
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Book Group Author(s): IEEE

Conference: IEEE International Ultrasonics Symposium (IUS) Location: Prague, CZECH REPUBLIC Date: JUL 21-25, 2013
Sponsor(s): IEEE
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Times Cited: 0

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By: Plessky, V.; Yantchev, V.; Daniau, W.; et al.
Book Group Author(s): IEEE
Conference: IEEE International Ultrasonics Symposium (IUS) Location: Prague, CZECH REPUBLIC Date: JUL 21-25, 2013
Sponsor(s): IEEE
2013 IEEE INTERNATIONAL ULTRASONICS SYMPOSIUM (IUS) Book Series: IEEE International Ultrasonics Symposium Pages: 263-266 Published: 2013

Times Cited: 0

9. Surface acoustic wave induced particle manipulation in a PDMS channel-principle concepts for continuous flow applications
By: Johansson, Linda; Enlund, Johannes; Johansson, Stefan; et al.
BIOMEDICAL MICRODEVICES Volume: 14 Issue: 2 Pages: 279-289 Published: APR 2012
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Times Cited: 16

10. Parametric Study of Thin-film Zero-Group Velocity Resonators (ZGVR)
By: Yantchev, V.; Arapan, L.; Ivanov, I.; et al.
Book Group Author(s): IEEE
Conference: IEEE International Ultrasonics Symposium (IUS) Location: Dresden, GERMANY Date: OCT 07-10, 2012
Sponsor(s): IEEE
2012 IEEE INTERNATIONAL ULTRASONICS SYMPOSIUM (IUS) Book Series: IEEE International Ultrasonics Symposium Pages: 307-310 Published: 2012

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By: Moreira, M. A.; Bjurstrom, J.; Yantchev, V.; et al.
Book Group Author(s): IOP

Conference: Symposium M on More than Moore - Novel Materials Approaches for Functionalized Silicon Based Microelectronics at Spring Meeting of the European-Materials-Research-Society (E-MRS) Location: Strasbourg, FRANCE Date: MAY 14-18, 2012
Sponsor(s): European Mat Res Soc (E-MRS)
E-MRS 2012 SPRING MEETING, SYMPOSIUM M: MORE THAN MOORE: NOVEL MATERIALS APPROACHES FOR FUNCTIONALIZED SILICON BASED MICROELECTRONICS Book Series: IOP Conference Series-Materials Science and Engineering Volume: 41 Article Number: 012014 Published: 2012
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Times Cited: 0

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By: Yantchev, V.; Katardjiev, I.; Plessky, V.
Book Group Author(s): IEEE
Conference: IEEE International Ultrasonics Symposium (IUS) Location: Orlando, FL Date: OCT 18-21, 2011
Sponsor(s): IEEE; PZFlex; Avago Technologies
2011 IEEE INTERNATIONAL ULTRASONICS SYMPOSIUM (IUS) Pages: 2503-2506 Published: 2012

Times Cited: 0

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Edited by: Kaltsas, G; Tsamis, C
Conference: 25th Eurosensors Conference Location: Athens, GREECE Date: SEP 04-07, 2011
EUROSENSORS XXV Book Series: Procedia Engineering Volume: 25 Published: 2011
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14. Polymer coated thin film plate acoustic resonators (FPAR) for gas sensing applications
By: Arapan, L.; Katardjiev, I.; Yantchev, V.; et al.
Book Group Author(s): IEEE
Conference: 5th Joint Conference of the 65th IEEE International Frequency Control Symposium/25th European Frequency and Time Forum Location: San Fransisco, CA Date: MAY 01-05, 2011
Sponsor(s): IEEE; IEEE UFFC; EFTF
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CONTROL SYMPOSIUM/EUROPEAN FREQUENCY AND TIME FORUM PROCEEDINGS Book Series: IEEE International Frequency Control Symposium Pages: 248-252 Published: 2011

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Book Group Author(s): IEEE
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21. Highly Mass-Sensitive Thin Film Plate Acoustic Resonators (FPAR)
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22. Coupling-of-Modes Analysis of Thin Film Plate Acoustic Wave Resonators Utilizing the S0 Lamb Mode
By: Yantchev, Ventsislav

IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 57 Issue: 4 Pages: 801-807 Published: APR 2010
Full Text from Publisher

Times Cited: 8

23. Micromachined thin film plate acoustic resonators (FPAR): Theory and applications
By: Yantchev, V.; Katardjiev, I.
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By: Yantchev, V.; Katardjiev, I.
Book Group Author(s): IEEE
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Times Cited: 0

25. Micromachined Thin Film Plate Acoustic Wave Resonators (FPAR): Part II
By: Yantchev, Ventsislav; Arapan, Lilia; Katardjiev, Ilia
IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 56 Issue: 12 Pages: 2701-2710 Published: DEC 2009
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Times Cited: 17

26. On the applicability of high frequency acoustic shear mode biosensing in view of thickness limitations set by the film resonance
By: Wingqvist, G.; Anderson, H.; Lennartsson, C.; et al.
BIOSENSORS & BIOELECTRONICS Volume: 24 Issue: 11 Pages: 3387-3390 Published: JUL 15 2009
Full Text from Publisher

Times Cited: 14

27. Fabrication Of GHz Range Oscillators Stabilized by Nano-Carbon-Diamond-Based Surface Acoustic Wave Resonators
By: Salut, R.; Ballandras, S.; Assouar, B.; et al.
Conference: 2009 IEEE International Ultrasonics Symposium Location: Rome, Italy
Date: 20-23 Sept. 2009
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Times Cited: 0

28. IC-compatible Power Oscillators Using Thin Film Plate Acoustic Resonators (FPAR)
By: Avramov, I.; Arapan, L.; Katardjiev, I.; et al.
Conference: 2009 IEEE International Ultrasonics Symposium Location: Rome, Italy
Date: 20-23 Sept. 2009
2009 IEEE International Ultrasonics Symposium Pages: 855-8 Published: 2009

Times Cited: 0

29. Zero Mass Loading Sensitivity of the S0 Lamb wave Resonance in Thin Film Plate Acoustic Resonators (FPARs)
By: Yantchev, V.
Conference: 2009 IEEE International Ultrasonics Symposium Location: Rome, Italy
Date: 20-23 Sept. 2009
2009 IEEE International Ultrasonics Symposium Pages: 2181-4 Published: 2009

Times Cited: 0

30. Interface acoustic wave based manipulation of sub-micrometer particles in microfluidic channels
By: Yantchev, V.; Enlund, J.; Katardjiev, I.; et al.
Conference: 2009 IEEE International Ultrasonics Symposium Location: Rome, Italy
Date: 20-23 Sept. 2009
2009 IEEE International Ultrasonics Symposium Pages: 617-20 Published: 2009

Times Cited: 0

31. Coupled Mode Approach to the Analysis of Thin Film S0 Lamb wave Resonators
By: Yantchev, V.; Arapan, L.; Katardjiev, I.

Book Group Author(s): IEEE
Conference: Joint Meeting of the 23rd European Frequency and Time Forum/IEEE International Frequency Control Symposium Location: Besancon, FRANCE Date: APR 20-24, 2009
Sponsor(s): Conseil Reg Franche Comte; Ville Besancon; NIST; IEEE, UFFC Soc; Jet Propuls Lab; Symmetricom; OEwaves; Vectron; Conseil Gen Doubs; Communaute Agglomerat Grand Besancon; Univ Franche Comte; Minist Rech & Enseignement Superieur; Soc Francaise Microtech & Chronometrie; Frequency Elect
2009 JOINT MEETING OF THE EUROPEAN FREQUENCY AND TIME FORUM AND THE IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM, VOLS 1 AND 2 Book Series: IEEE International Frequency Control Symposium Pages: 79-84 Published: 2009

Times Cited: 0

32. Optimisation of a smooth multilayer Nickel Silicide surface for ALN growth
By: Martin, D. M.; Enlund, J.; Yantchev, V.; et al.
Edited by: Johansson, LSO; Andersen, JN; Gothelid, M; et al.
Conference: 17th International Vacuum Congress/13th International Conference on Surface Science/Internatinal Conference on Nanoscience and Technology Location: Stockholm, SWEDEN Date: JUL 02-06, 2007
Sponsor(s): Swedish Vacuum Soc
PROCEEDINGS OF THE 17TH INTERNATIONAL VACUUM CONGRESS/13TH INTERNATIONAL CONFERENCE ON SURFACE SCIENCE/INTERNATIONAL CONFERENCE ON NANOSCIENCE AND TECHNOLOGY Book Series: Journal of Physics Conference Series Volume: 100 Article Number: 042014 Published: 2008
Full Text from Publisher

Times Cited: 3

33. Temperature Compensation of Thin AlN Film Resonators utilizing the Lowest order Symmetric Lamb mode
By: Wingqvist, G.; Arapan, L.; Yantchev, V.; et al.
Book Group Author(s): IEEE
Conference: IEEE Ultrasonics Symposium Location: Beijing, PEOPLES R CHINA Date: NOV 02-05, 2008
Sponsor(s): IEEE
2008 IEEE ULTRASONICS SYMPOSIUM, VOLS 1-4 AND APPENDIX Book Series: ULTRASONICS SYMPOSIUM Pages: 1207-1210 Published: 2008

Times Cited: 0

34. Analysis of Resonant SAW - Plate BAW Interaction in Periodical Couplers
By: Yantchev, V.; Plessky, V.; Katardjiev, I.

Book Group Author(s): IEEE
Conference: IEEE Ultrasonics Symposium Location: Beijing, PEOPLES R CHINA Date: NOV 02-05, 2008
Sponsor(s): IEEE
2008 IEEE ULTRASONICS SYMPOSIUM, VOLS 1-4 AND APPENDIX Book Series: ULTRASONICS SYMPOSIUM Pages: 86-89 Published: 2008

Times Cited: 0

35. Mass sensitivity of thin film resonator devices
By: Wingqvist, G.; Yantchev, V.; Bjurstrom, J.; et al.
Conference: 2007 IEEE International Frequency Control Symposium Jointly with the 21st European Frequency and Time Forum Location: Geneva, Switzerland Date: 29 May-1 June 2007
2007 IEEE International Frequency Control Symposium Jointly with the 21st European Frequency and Time Forum Pages: 581-6 Published: 2007

Times Cited: 0

36. Thin AlN film resonators utilizing the lowest order symmetric lamb mode: further developments
By: Yantchev, V.; Katardjiev, I.
Conference: 2007 IEEE International Frequency Control Symposium Jointly with the 21st European Frequency and Time Forum Location: Geneva, Switzerland Date: 29 May-1 June 2007
2007 IEEE International Frequency Control Symposium Jointly with the 21st European Frequency and Time Forum Pages: 1067-72 Published: 2007

Times Cited: 0

37. Micromachined thin film plate acoustic resonators utilizing the lowest order symmetric lamb wave mode
By: Yantchev, Ventsislav; Katardjiev, Ilia
IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 54 Issue: 1 Pages: 87-95 Published: JAN 2007
Full Text from Publisher

Times Cited: 46

38. Mass sensitivity of thin film resonator devices
By: Wingqvist, G.; Yantchev, V.; Jurstroin, J.; et al.
Book Group Author(s): IEEE

Conference: Joint IEEE International Frequency Control Symposium/21st European Frequency and Time Forum Location: Geneva, SWITZERLAND Date: MAY 29-JUN 01, 2007
Sponsor(s): IEEE
PROCEEDINGS OF THE 2007 IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM-JOINTLY WITH THE 21ST EUROPEAN FREQUENCY AND TIME FORUM, VOLS 1-4 Pages: 581-586 Published: 2007

Times Cited: 1

39. Thin AlN film resonators utilizing the lowest order symmetric lamb mode: Further developments
By: Yantchev, V.; Katardjiev, I.
Book Group Author(s): IEEE
Conference: Joint IEEE International Frequency Control Symposium/21st European Frequency and Time Forum Location: Geneva, SWITZERLAND Date: MAY 29-JUN 01, 2007
Sponsor(s): IEEE
PROCEEDINGS OF THE 2007 IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM-JOINTLY WITH THE 21ST EUROPEAN FREQUENCY AND TIME FORUM, VOLS 1-4 Pages: 1067-1072 Published: 2007

Times Cited: 2

40. Design and fabrication of temperature compensated liquid FBAR sensors
By: Bjurstrom, J.; Wingqvist, G.; Yantchev, V.; et al.
Conference: 2006 IEEE Ultrasonics Symposium Location: Vancouver, BC, Canada Date: 3-6 Oct. 2006
2006 IEEE Ultrasonics Symposium (IEEE Cat. No.06CH37777) Pages: 4 pp. Published: 2006

Times Cited: 0

41. Electric field sensitivity of thin film resonators based on piezoelectric AlN thin films
By: Enlund, J.; Yantchev, V.; Katardjiev, I.
Conference: 2006 IEEE Ultrasonics Symposium Location: Vancouver, BC, Canada Date: 3-6 Oct. 2006
2006 IEEE Ultrasonics Symposium (IEEE Cat. No.06CH37777) Pages: 4 pp. Published: 2006

Times Cited: 0

42. Electric field Sensitivity of Thin Film Resonators Based on Piezoelectric AlN thin films
By: Enlund, J.; Yantchev, V.; Katardjiev, I.
Book Group Author(s): IEEE
Conference: IEEE Ultrasonics Symposium Location: Vancouver, CANADA Date: OCT 03-06, 2006
Sponsor(s): IEEE
2006 IEEE ULTRASONICS SYMPOSIUM, VOLS 1-5, PROCEEDINGS Book Series: ULTRASONICS SYMPOSIUM Pages: 468-471 Published: 2006

Times Cited: 3

43. Design and Fabrication of Temperature Compensated Liquid FBAR Sensors
By: Bjurstrom, J.; Wingqvist, G.; Yantchev, V.; et al.
Book Group Author(s): IEEE
Conference: IEEE Ultrasonics Symposium Location: Vancouver, CANADA Date: OCT 03-06, 2006
Sponsor(s): IEEE
2006 IEEE ULTRASONICS SYMPOSIUM, VOLS 1-5, PROCEEDINGS Book Series: ULTRASONICS SYMPOSIUM Pages: 898-901 Published: 2006

Times Cited: 0

44. Design and fabrication of thin film Lamb wave resonators utilizing longitudinal wave and Interdigital transducers
By: Yantchev, V; Katardjiev, I
Book Group Author(s): IEEE
Conference: IEEE International Ultrasonics Symposium Location: Rotterdam, NETHERLANDS Date: SEP 18-21, 2005
Sponsor(s): IEEE
2005 IEEE ULTRASONICS SYMPOSIUM, VOLS 1-4 Book Series: Ultrasonics Symposium Pages: 1580-1583 Published: 2005

Times Cited: 1

45. Coupling-of-modes analysis of STW resonators including loss mechanism
By: Yantchev, VM; Strashilov, VL
IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 49 Issue: 3 Pages: 331-336 Published: MAR 2002
Full Text from Publisher

Times Cited: 4

C) Research review articles

1. Thin film Lamb wave resonators in frequency control and sensing applications: a review
By: Yantchev, Ventsislav; Katardjiev, Ilia
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 23 Issue: 4 Article Number: 043001 Published: APR 2013
Times Cited: 6

2. Recent developments in thin film electro-acoustic technology for biosensor applications
By: Katardjiev, I.; Yantchev, V.
VACUUM Volume: 86 Issue: 5 Special Issue (**Invited**): SI Pages: 520-531 Published: JAN 5 2012
Times Cited: 18

D) Top 5 most cited articles

1. Shear mode AlN thin film electro-acoustic resonant sensor operation in viscous media
By: Wingqvist, G.; Bjurstrom, J.; Liljeholm, L.; et al.
SENSORS AND ACTUATORS B-CHEMICAL Volume: 123 Issue: 1 Pages: 466-473 Published: APR 10 2007

Times cited: 64

2. Micromachined thin film plate acoustic resonators utilizing the lowest order symmetric lamb wave mode
By: Yantchev, Ventsislav; Katardjiev, Ilia
IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 54 Issue: 1 Pages: 87-95 Published: JAN 2007

Times cited: 47

3. Temperature compensation of liquid FBAR sensors
By: Bjurstrom, J.; Wingqvist, G.; Yantchev, V.; et al.
JOURNAL OF MICROMECHANICS AND MICROENGINEERING Volume: 17 Issue: 3 Pages: 651-658 Published: MAR 2007

Times cited: 39

4. Lateral-field-excited thin-film Lamb wave resonator
By: Bjurstrom, J; Katardjiev, I; Yantchev, V

APPLIED PHYSICS LETTERS Volume: 86 Issue: 15 Article Number: 154103 Published: APR 11 2005

Times cited: 33

5. Aluminum scandium nitride thin-film bulk acoustic resonators for wide band applications
By: Moreira, Milena; Bjurstrom, Johan; Katardjev, Ilia; et al.
VACUUM Volume: 86 Issue: 1 Pages: 23-26 Published: JUL 4 2011

Times cited: 32

E) Patents

I.Katardjiev and **V.Yantchev** (WO/2012/156818), International Application No.: PCT/IB2012/001094 "A Passive Radio Triggered Switch with ID Functionality"

V.Yantchev et. al., (WO/2010/123453), International Application No.: PCT/SE2010/050455, “Device and Method for Manipulating Utilizing Surface Acoustic waves"

CV

Name: Ilia Katardjiev	**Doctorial degree:** 1989-07-07
Birthdate: 19550423	**Academic title:** Professor
Gender: Male	**Employer:** Uppsala universitet

Research education

Dissertation title (swe)

Teoretiska och experimentella studier av yta evolution under jon bombanemang

Dissertation title (en)

Theoretical and experimental studies of surface evolution during ion bombardment

Organisation	Unit	Supervisor
Salford University, Great Britain and Northern Ireland Not Sweden - Higher Education institutes	Department of Electrical Engineering	George Carter

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20299. Annan elektroteknik och elektronik		1989-07-07

CV

Name: Ventsislav Yantchev	**Doctorial degree:** 2004-04-15
Birthdate: 19760522	**Academic title:** Docent
Gender: Male	**Employer:** No current employer

Research education

Dissertation title (swe)
Analysis of Surface Transverse Waves on Quartz in Resonant Structures for Oscillator and Sensing Applications

Dissertation title (en)
Analysis of Surface Transverse Waves on Quartz in Resonant Structures for Oscillator and Sensing Applications

Organisation	Unit	Supervisor
Univesrsity of Sofia, Bulgaria Not Sweden - Higher Education institutes	Faculty of Physics	Vesseline Strashilov

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20299. Annan elektroteknik och elektronik		2004-04-15

Publications

Name: Ilia Katardjiev	**Doctorial degree:** 1989-07-07
Birthdate: 19550423	**Academic title:** Professor
Gender: Male	**Employer:** Uppsala universitet

Katardjiev, Ilia has not added any publications to the application.

Publications

Name: Ventsislav Yantchev	**Doctorial degree:** 2004-04-15
Birthdate: 19760522	**Academic title:** Docent
Gender: Male	**Employer:** No current employer

Yantchev, Ventsislav has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.